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ELECTRICAL CONTROL PACKAGE FOR
BRAYTON POWER CONVERSION SYSTEM

FINAL REPORT

By J. H. Shank - Project Manager

Contract NAS3-11784
Hayes International Corporation

January 1969

~~NASA CR-72479~~ is an erroneous number and should be NASA CR-72497. Please correct your copy of the report to reflect this change.

~~NASA CR-72479~~
NASA-CR-72497

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Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Jack H. Shank, Project Manager

HAYES INTERNATIONAL CORPORATION
Missile and Space Support Division

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NASA-CR-72497

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FOR
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CONTRACT NAS3-11784

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ELECTRICAL CONTROL PACKAGE FOR THE BRAYTON POWER CONVERSION SYSTEM

HAYES INTERNATIONAL CORPORATION
MISSILE AND SPACE SUPPORT DIVISION

SUMMARY

The NASA Lewis Research Center is currently engaged in a Brayton cycle space power technology program. The Brayton Power Conversion System (PCS) has applicability for solar, radioisotopes, and nuclear space power systems in the net output power range of 2.25 to 10.5 KWe at 1200 hertz. The Brayton PCS is designed to operate unattended in space for five (5) years.

The Brayton Rotating Unit (BRU) for the Brayton PCS is a constant speed single shaft unit. The 1200 hertz alternator section of the shaft is supported by gas bearings with a compressor overhung on one end of the single shaft and a turbine overhung on the other end. A mixture of gases is used as the working fluid to convert the heat energy input into electrical energy as the output of the alternator.

The Electrical Control Package contains the circuitry necessary to maintain the alternator output within finite limits of voltage and frequency and also functions as the power distribution center for the alternator output power. This circuitry consists of the alternator series field power supply, the voltage regulator for controlling the shunt field supply, the three channel speed control, which regulates the power dissipated by the Parasitic Load Resistor and four relays for controlling vehicle load, alternator field and gas bottle heater power.

The Electrical Control Package is designed for base mounting to a separate cold plate which receives heat by conduction from the Control Package and dissipates this heat into a liquid coolant flow.

INTRODUCTION

The Electrical Control Package described in this report was designed as a component of the Brayton Power Conversion System to be tested in the NASA Lewis Research Center's Space Power Facility at the Plum Brook Station. The electrical circuit design used was supplied by the Lewis Research Center, as were the electrical components, and is an outgrowth of the "bread-board" development testing of a rack mounted, air cooled unit presently in operation. Design requirements for the Electrical Control Package were detailed in Lewis Research Center specification C-356772, Rev. A. A circuit thermal analysis was performed in conjunction with the preliminary layout of the Control Package to assure that the methods of component installation utilized permitted the components to operate within their derating curves. Maximum advantage was taken of the allowable mounting area on the external Cold Plate to insure accessibility within the enclosure and to allow room for future component installation. It was felt that the flexibility gained by this approach at the expense of added weight and increased package size was justifiable in view of the intended development test use of the equipment. Low power testing of the completed Control Packages verified proper circuit operation.

CIRCUIT OPERATION

The Electrical Control Package contains the circuits necessary to maintain the alternator of the Brayton Rotating Unit within finite limits of voltage and frequency. It also functions as the power distribution center for the alternator output power.

The alternator field excitation current is supplied by the series field power supply, supplemented as required by the shunt field supply to maintain an alternator output voltage of 208 volts line to line, 120 volts line to neutral. The series field amplitude is directly proportional to the alternator output line current. The voltage regulator senses the output voltage of the alternator and controls the shunt field current flow in order to maintain the required output voltage.

The constant speed of the Brayton Rotating Unit is controlled by the three speed control channels within the Electrical Control Package. As the net shaft input power from the turbine varies or as the demand for the useful vehicle load varies, the speed control maintains a constant alternator shaft speed by dissipating the excess generated power in an electrical parasitic load located external to the Electrical Control Package. Therefore, with a constant input power to the alternator, the output load on the alternator is maintained constant by varying the electrical amplitude of the parasitic load so that the sum of the useful vehicle load and the parasitic load is constant.

The following paragraphs describe in detail the operation of the series-field power supply, the voltage regulator, the speed control and the function of the four relays.

Series-Field Power Supply

The series-field power supply (reference schematic page 21), which consists basically of current transformers T501 through T503, a bridge rectifier, CR501 through CR506, and output capacitors C501 and C502, supplies excitation to the alternator for the purpose of maintaining system fault currents. The fault currents are maintained for a time sufficient for the protection logic to take positive corrective action. The minimum fault current capacity deemed necessary in the system is three per unit with a duration of five seconds. The series-field controller also reduces the load requirements on the voltage regulator by supplying a part of the alternator field ampere turns as needed by the system during normal loading. With rated (1 PU) load on the alternator, approximately 50 percent of the total ampere-turns is supplied by this controller. During a three per-unit system fault, the series-field controller delivers 100 percent of the excitation requirements or approximately 375 watts. Output capacitors are provided in the controller to suppress voltage transients which may occur due to change in system load.

Voltage Regulator

The voltage regulator (reference schematic page 22) operates in a switching mode. The regulator fundamentally consists of a voltage-sensor, a voltage-reference, a comparator, an amplifier, an output power stage, and a field-current limiter. The regulator senses the alternator output such that the average of the three-phase-voltages is held constant.

The DC output voltage of the sensor together with its superimposed line ripple is compared with a reference to drive the amplification and power stages at a frequency of 3600 pulses per second. This synchronization of the regulator function to the line occurs in the comparator by virtue of the line ripple. While operating within the active control range, the power stage pulse width is proprotional to the error voltage. This regulator synchronization to the line improves both the voltage-modulation level of the alternator output and the response time of the system when compared to the same regulator not synchronized to the line. The operating mode of the regulator has a voltage gain of approximately 100. The current-limiter module limits the field current to an average of 5 amperes. Manual control of the regulator can be obtained from an external source. This feature is provided in case an abnormal system operating mode should occur.

Speed Control

The speed control (reference schematics pages 23 , 24 and 25) consists of a transistorized frequency sensor, a magnetic amplifier and phase controlled SCR power output stages. The speed-controller effectively functions in a linear control mode in which the parasitic power is a function of line frequency.

The sensing stage which basically consist s of two R-C networks including transistor switches develops a DC output current of sufficient mangitude to drive the first stage of magnetic amplification. The effect of the transistor switching is to modulate the energy level existing in each of the two networks. The sensor output current which is a function of transistor saturation time and therefore line frequency is proportional to the deviation of the frequency from a given set point.

Two stages of amplification are utilized in the speed-controller. Each stage consists of two full-wave magnetic-amplifiers in which the outputs are added differentially. The conduction angle of each amplifier with zero control is set to approximately 90 degrees by the use of leakage-reset control. This control mode tends to linearize the control characteristic and to reduce the effect of changes in ambient temperature. Gain adjustment is accomplished by controlling the feedback on the second stage.

The type of phase control (firing circuit) utilized in the output stage allows the gate-power dissipated in the SCR's to be minimized. The gate signal for all practical purposes goes to zero at the instant of SCR saturation. The controlling element in the firing circuit is a saturable reactor. The frequency-control range of each of the three controllers is shifted such that one controller is fully conducting prior to the turn-on of the succeeding controller. The parasitic power capability of each controller when fully conducting is approximately 0.6 per unit or 1.8 per unit with three controllers. Manual control of the speed-controller can be obtained from an external source. This feature is provided in case an abnormal system operating mode should occur.

Relays

The arrangement of the four relays in the control circuit is shown in the Electrical Control Package schematic, page 21. K501 is a double pole, double throw, 28 volt DC relay which removes the shunt-field regulator from the shunt field and places a fixed field on the shunt field of the alternator. This fixed field is used as an emergency field if a failure occurs in the shunt field regulator and to place a field on the alternator during shut-down. K502 is a double pole, double throw, 28 volt DC relay which is being used as a single pole, single throw relay to supply field flashing to the alternator shunt field. K502 enables removal of the power to the shunt field during cooldown, following system shut-down. K503 is a three pole, single throw, 1200 hertz, 208 volt relay called the vehicle load breaker. When K503 is closed, 1200 hertz power is available to the vehicle. K504 is a two pole, single throw, 56 volt DC relay which is used to supply power to a gas bottle heater during the pre-start procedures.

DESIGN

The final configuration of the Electrical Control Package is shown on Hayes International Corporation drawing no 68-00002, sheets 1 and 2, pages 33 and 34. Photographs, pages 35 through 41, show the external and internal views of the completed unit.

The layout of the enclosure was designed to permit ease of accessibility to all components, to allow clear areas for future component installation with minimum rework and at the same time to provide adequate heat transfer paths from the components to the external cold plate. As a result of this effort, the three fuse blocks are the only components which require removal to allow access to other components or the Control Package installation hardware.

The enclosure is of welded contruction using 6061-T6 aluminum alloy sheet. The base dimensions are 27 1/2" x 27 1/2" and the overall height is 8 1/2". The enclosure is designed for base mounting to an external cold plate which dissipates the heat generated by the components within the enclosure to a liquid coolant. Tapped holes are provided in the cold plate on 2 inch centers for use in attaching the enclosure to the cold plate. Matched holes have been provided in the base of the enclosure (105 places) at each accessible location to provide the maximum amount of heat transfer area and to provide flexibility in making modifications within the enclosure without requiring an additional match drilling operation. Installation of the enclosure to the cold plate is accomplished utilizing 1/4-28UNF bolts torqued to 85 in-lbs. The base of the enclosure contacting the cold plate has been machined flat within .005 inch TIR within any 10 inch span and .002 inch TIR within any 4 inch span and has a surface finish of 32 microinches. Heat transfer surfaces are protected from corrosion by an alodine treatment. External surfaces, other than the base, have been painted per MIL-STD-171.

Electrical connections to the package are provided by two terminal boards and four connectors. Terminal Board No. 1 provides 27 through-studs, 8 each 1/4-28 and 19 each #10-32, for terminating leads for the Brayton Rotating Unit, the vehicle loads and the DC power supply. Terminal Board #2 provides 11 each #10-32 studs for outputs to the Parasitic Load Resistors. Connector J-1 provides leads for the activation coils and indicators for Relays K501 through K504; connector J-2 provides leads for internal current and voltage measurements; connector J-3 contains the chassis ground, the DC common, the speed control override, the voltage regulator inhibit, and the base temperature measurement circuits; the development temperature leads are contained in connector J-4. Access to the nine potentiometers (2 in each channel of the speed control and 3 in the voltage regulator circuit) are provided in the Package cover by removable button plugs. The cover provides protection against mechanical damage and contamination only and is not a hermetic seal.

Internally, the components have been grouped on a functional, subcircuit basis to ease circuit traceability and optimize wire routing. The allowable base dimensions of the enclosure permitted the mounting of most of the major power dissipating components either directly to the base or on minimum size brackets welded directly to the base. As a result of this "horizontal" arrangement of the package, most components are accessible for trouble-shooting or replacement without removing other components. The exceptions are the Silicon Controlled Rectifiers under the three fuse blocks. In addition, this arrangement minimizes the thermal resistance to sink from each component by reducing the heat path length.

Thirteen printed circuit boards are utilized in the packaging of the circuitry; three in each channel of the speed control and four in the voltage regulator-exciter section. To provide a conduction heat path to the base of the enclosure, an aluminum bracket has been added to each printed circuit assembly. This bracket is installed between the circuit components and the circuit boards. Holes through the bracket match the component terminal lead holes in the printed circuit board. Terminals leads are insulated by PVC tubing. A positive heat path from the components to the bracket is supplied by the epoxy and conformal coating used to stabilize and protect the components per KSC-SPEC-E-0001. The circuit board is attached to the bracket by four screws, one in each corner of the boards. The assembly is mounted to the base of the enclosure by two #8-32 screws through slotted holes in the mounting flange of the bracket into tapped holes in the base. The connectors for the printed circuit assemblies are mounted on the walls of the enclosure. This method of printed circuit assembly provides a unit that is easily removable, permits replacement of components and provides a good heat path from the components to the base of the enclosure. Printed circuit assembly drawings of seven of the assemblies are included on pages 26 through 32. The assemblies for speed control channels B and C are identical to the assemblies shown for Channel A.

The installation methods used for the remainder of the circuit components are shown in the photographs and on assembly drawing 68-00002. Wiring used within the Package meets the requirements of MIL-W-16878 for wire sizes #16AWG and above and MIL-W-5086 for #12AWG and below. Soldering quality requirements were specified by NASA Quality Publication NPC 200-4. Power is distributed from the main power leads by stud type terminal boards while solder type terminal boards are used as wiring interconnect terminals for the saturable reactors, potentiometers, transformers and firing circuit resistors. These terminal boards also provide mounting locations for fixed value resistors which will be used to replace the potentiometers once required resistance values are obtained.

Circuit access points for the insertion of test equipment to evaluate certain circuit parameters have been provided. These measurements and the terminal points provided are listed in table 1, page 17.

INSTALLATION AND MAINTENANCE

The following steps are involved in the installation of the Electrical Control Package to the cold plate:

1. Remove Control Package cover.

2. Remove two installation screws from each of three fuse blocks.

3. Position Control Package on the Cold Plate and install 105 each 1/4-28UNF bolts, with washers, thru the base of the Control Package into tapped holes in the Cold Plate. Shift fuse blocks to gain access to sixteen (16) bolt locations. Apply 85 inch-lbs. of torque to the bolts.

4. Reinstall fuse block mounting screws.

5. Reinstall cover.

The following information is intended as preventive maintenance and inspection check points to be used during test "down time" and for removal and reinstallation of components.

1. The following torque values apply for the stud mounted diodes, transistors and SCRS.

   #10-32 stud size - 10 inch-lbs.
   1/4-28 stud size - 20 inch-lbs.

2. Nuts on the relay terminals should be torqued to the following values:

Relays K501 and K502	60 in - oz.
Relays K503 and K504	15 in - lbs.

3. After installing contacts in the printed circuit connectors, verify that proper contact exists between the connector tynes and the printed circuit. Careless installation of these contacts may spread the tynes so that no continuity exists between the printed circuit and the tynes.

4. Inspect components, printed circuit boards and wiring insulation for evidence of excessive heating.

5. When connectors J-1 thru J-4 are not in use, protective caps should be installed Verify that connector pins are not damaged.

6. Inspect stud type terminal boards to insure that all connectors are tight.

7. If solder type terminal boards are removed and reinstalled, ensure that mylar film insulator is installed between the terminal board and the enclosure mounting surface.

THERMAL ANALYSIS SUMMARY

A circuit thermal analysis was performed as a part of the detail design effort to assure that the components were operating within the limits of their derating curves. In performing this analysis, the power dissipated by each resistive component was computed using waveform and voltage data supplied by Lewis Research Center. Component operating temperatures were then determined by calculating the differential temperature required to transfer this heat from the component through its mounting brackets to the base of the enclosure and thence to the cold plate.

To simplify calculations, the base of the enclosure was assumed to operate at a uniform Δt above the cold plate maximum temperature. This Δt was computed as that required to distribute 50 watts through the required base area and transfer this heat across the enclosure base - cold plate interface, based upon a contact conductance of 100 BTU/hr - ft ^{2} - ^{o}F and a maximum heat transfer rate of 10 watts per fastener (2.5 watts/in^2). The value of power dissipation used (50 watts) was applied to the enclosure base at the interface of the mounting bracket for Q404, Q405 and Q407. This Δt was calculated to be 4^{o}C. Thus, for a cold plate maximum temperature of 65.6^{o}C (150^o F) the base of the enclosure was assumed to be at a uniform temperature of 69.6^{o}C.

The operating temperature of those components installed directly on the base of the enclosure was determined based on the contact thermal resistance of their interface area only. A value of .8^{o}C-in ^{2}/watt was used for this contact resistance (Reference NAVSHIPS, Document 900.192, page 10, for low contact pressure and 125 rms surface finish.)

The stud mounted diodes, transistors and SCR's are insulated from their mounting plates by a .031 thick beryllium oxide washer under the case and a .005 thick mica washer under the nut. With this arrangement, a thermal resistance from case to mounting bracket of 1^{o}C/watt was assumed.

The operating temperature of the printed circuit board mounted components was determined in the following manner. The power dissipated in the form of heat of all components on the board was applied to the edge of the mounting bracket opposite the base of the enclosure. The Δt required to transfer this heat through the bracket and across the bracket to base interface was then calculated. The sink temperature for each component was then taken to be the enclosure base temperature plus this Δt. The heat path from the component to the bracket is through the epoxy used to bond the components to the bracket. The path area is equal to the projected area of the component and the path length was assumed to be .35 times the component radius for tubular components and .032 inches for the transistors. The thermal conductivity values used for the epoxy was .0048 $\frac{\text{watts-in.}}{^{o}\text{C-in}^2}$

Results of this analysis indicated that all components would operate within their rated power at the cold plate design point temperature of 100°F. However, at the cold plate maximum operating temperature of 150°F, resistors R115, R215 and R315, mounted on the magnetic amplifier #2 circuit board in each of the speed control channels, exceeded their rated power by 25%. Each of these 100 ohm resistors was replaced by 2 each 200 ohm resistors connected in parallel, reducing power dissipated by each resistor so that operation within the derating curve was obtained. Resistors R114, R214 and R314 were treated in the same manner to maintain circuit balance.

Table 2, pages 18 and 19, summarizes component power dissipations, Δt with respect to the Cold Plate and the ratio of actual versus maximum permissible power dissipation as determined from the component derating curves. Table 3, page 20, lists the location of the iron-constantan thermocouples installed and their connector terminations.

TESTING

Prior to performing the low power excitation tests, the Control Package were subjected to a continuity test to assure that all wiring was properly terminated and that all stud-mounted diodes and transistors were electrically isolated from the enclosure. The four relays were also cycled to insure proper operation of the activation coils and indicator circuits.

The objective of the low power test of the voltage regulator circuit was to demonstrate the ability of this circuit to control the shunt field current flow. Because a variable frequency AC power supply with the required power output was not available, separate DC supplies were used to simulate the output of shunt field supply bridge retifier CR401, and the voltage sensing bridge rectifier. A 30 ohm, 100 watt resistor, a 12 VDC lamp and a multimeter were placed in series across the Control Package output terminals to the alternator field to supply shunt field circuit loading and load current measurement capability. The output voltage of power supply #1, representing the output of bridge rectifier CR401, was set at 35 VDC and potentiometer R424 adjusted to give a 15 VDC output from the voltage reference circuit, as indicated by multimeter #1. Since there was no output at this time from the voltage sensing circuit (power supply #2), transistor Q405 was in the conduction mode permitting a shunt field current flow of 1.5 amps through the load. The output voltage from power supply #2, representing the alternator voltage sensing circuit output, was then increased until shunt field current flow cut-off was reached. Shunt field cut-off occurred at an output voltage of 28 VDC from power supply #2. The ability of potentiometer R403 to control this cut-off point was then verified by changing the potentiometer setting and observing the shunt field output.

The ability of the speed control circuit to regulate the power diverted to the external parasitic load was verified by the low power testing of the three speed control channels. The variable frequency power supply used was rated at 100 VA output, requiring that the three sections of each speed control channel be tested independently. The following procedure was used to test channel A of the speed control. Channels B and C were tested in a similar manner.

To supply the load for the ØA section of channel A, a 25 watt incadescent lamp was connected to the ØA firing circuit output terminal on TB2. An oscilloscope was connected in parallel with this load to observe the conduction behavior of the SCR's. The power supply was then connected to the ØA firing circuit, and the power supply frequency adjusted to 1200 hertz. The gain control potentiometer for channel A, R119, was adjusted for maximum gain and the output voltage from the power supply was slowly increased to 120 VAC. The frequency control potentiometer for Channel A, R104, was adjusted until SCR conduction was initiated as indicated on the oscilloscope. The power supply frequency was then increased until the maximum conduction angle of the SCR's was reached. This frequency was noted and the power supply output voltage reduced to zero. The load was then removed from the ØA firing circuit output terminals and placed across the ØB output terminals. Since the power for operation of the frequency detector and amplifier circuits is taken from the ØA input for Channel A, the power supply output was connected to both ØA and ØB firing circuits. The above procedure was repeated to verify the operation of the ØB firing circuit. To test the ØC firing circuit, the load was removed from ØB and placed across the ØC firing circuit outputs. The ØB power lead to the power supply was replaced with the ØC firing circuit lead and the test procedure was repeated.

With maximum gain settings for the magnetic amplifier circuit and the frequency control set to initiate SCR conduction at 1200 hertz, the frequency at which maximum conduction was reached in each section of the three speed control channels varied from 1208 to 1213 hertz. The load current drawn at maximum conduction during these low power tests was approximately 1.5 amps.

TABLE I

CIRCUIT TEST POINTS

MEASUREMENT	TERMINALS	
Output, Voltage rectifier C401	C405 (+)	C405 (-)
Output, Reference Voltage Circuit, VRE	TB7-18	C405 (-)
Output, Voltage Sensing Circuit rectifier, VRE	TB7-1	TB7-2
V_{B1}, Q401	TB7-2	TB7-9
Voltage Across SCR firing circuit resistors	Resistor mounting terminals on TB3, TB4 and TB5.	
Frequency detector output, Speed Control		
Channel A	TP3	TP4
Channel B	TP7	TP8
Channel C	TP11	TP12
Output Current Magnetic Amplifier #1		
Channel A	TP1	TP2
	(Remove Wire #281A20)	
Channel B	TP5	TP6
	(Remove Wire #282A20)	
Channel C	TP9	TP10
	(Remove Wire #283A20)	

TABLE II

COMPONENT	POWER DISSIPATED (WATTS)	Δt TO COLD PLATE (°C)	% RATED POWER DISSIPATED AT MAXIMUM COLD PLATE TEMPERATURE
R101, R201, R301	.095	29	30%
R102, R202, R302	.87	84	42%
R103, R203, R303	.66	69	29%
R105, R205, R305	.095	30	30%
R106, R206, R306	.67	86	33%
Q101, 201, 301	.004	21	.3%
Q102, 202, 302	.004	21	.3%
Q103, 203, 303	.004	21	.3%
Q104, 204, 304	.004	21	.3%
CR102, 202, 302	.016	23	3%
CR105, 205, 305	.016	23	3%
R107, R207, R307	.009	10	8%
R108, R208, R308	.45	42	20%
R109, R209, R309	.004	10	4%
R110, R210, R310	.005	10	1.2%
R111, R211, R311	.27	30	10%
R116, R216, R316	.009	10	7%
CR106, 206, 306	.1	39	29%
CR107, 207, 307	.1	39	29%
CR108, 208, 308	.1	39	29%
CR109, 209, 309	.1	39	29%
R112, R212, R312	.001	20	
R113, R213, R313	.016	20	13%
R114, R214, R314	.001	19	
R114A, R214A, R314A	.001	19	
R115, R215, R315	.75	75	34%
R115A, R215A, R315A	.75	74	34%
R117, R217, R317	.08	27	22%
R118, R218, R318	.02	21	6%
CR110, thru CR315	.1	49	30%
R401	.09	16	45%
R402	.12	19	60%
R404	.06	13	30%
CR403	.1	37	29%
CR404	.1	37	29%
CR405	.1	37	29%

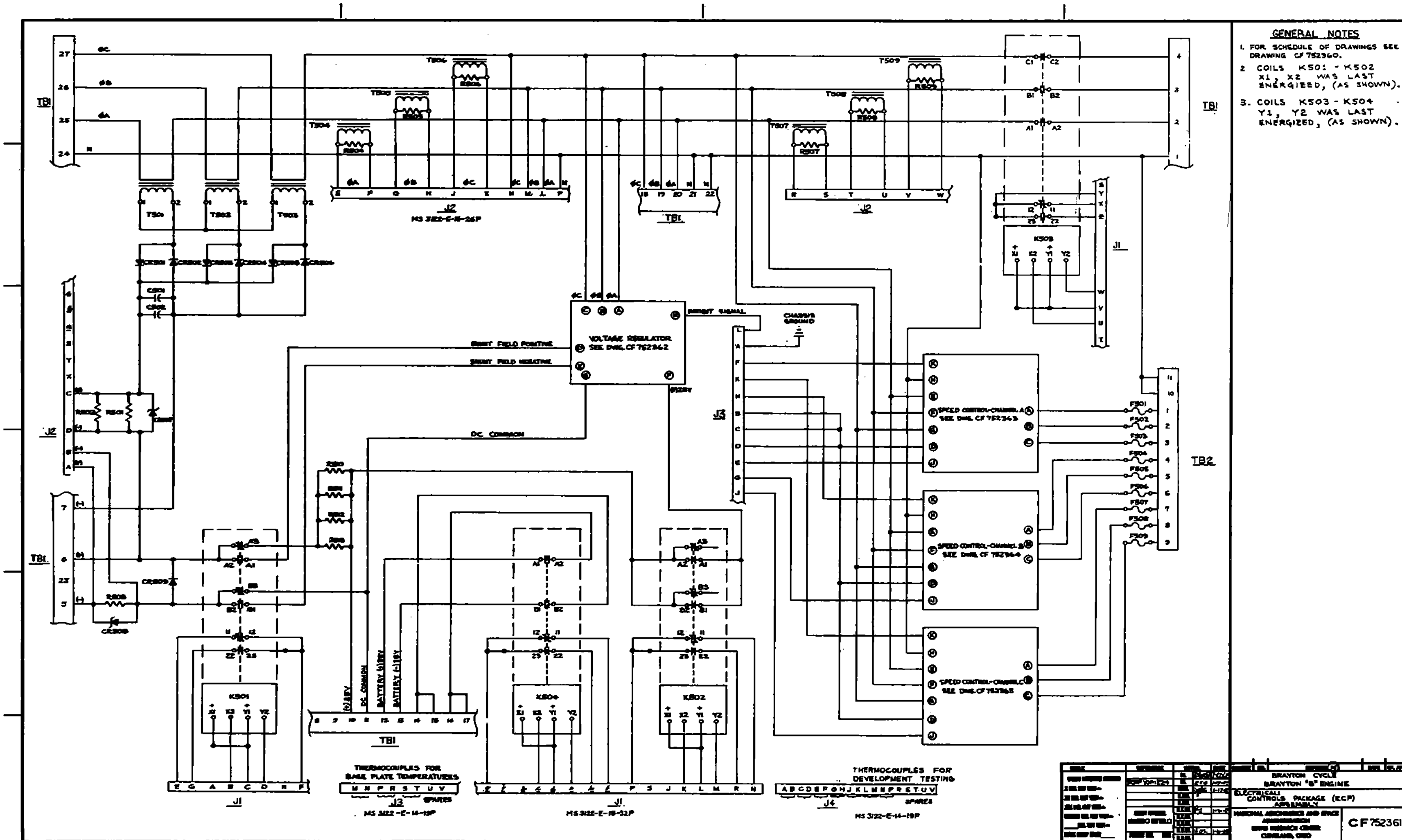
(Continued)

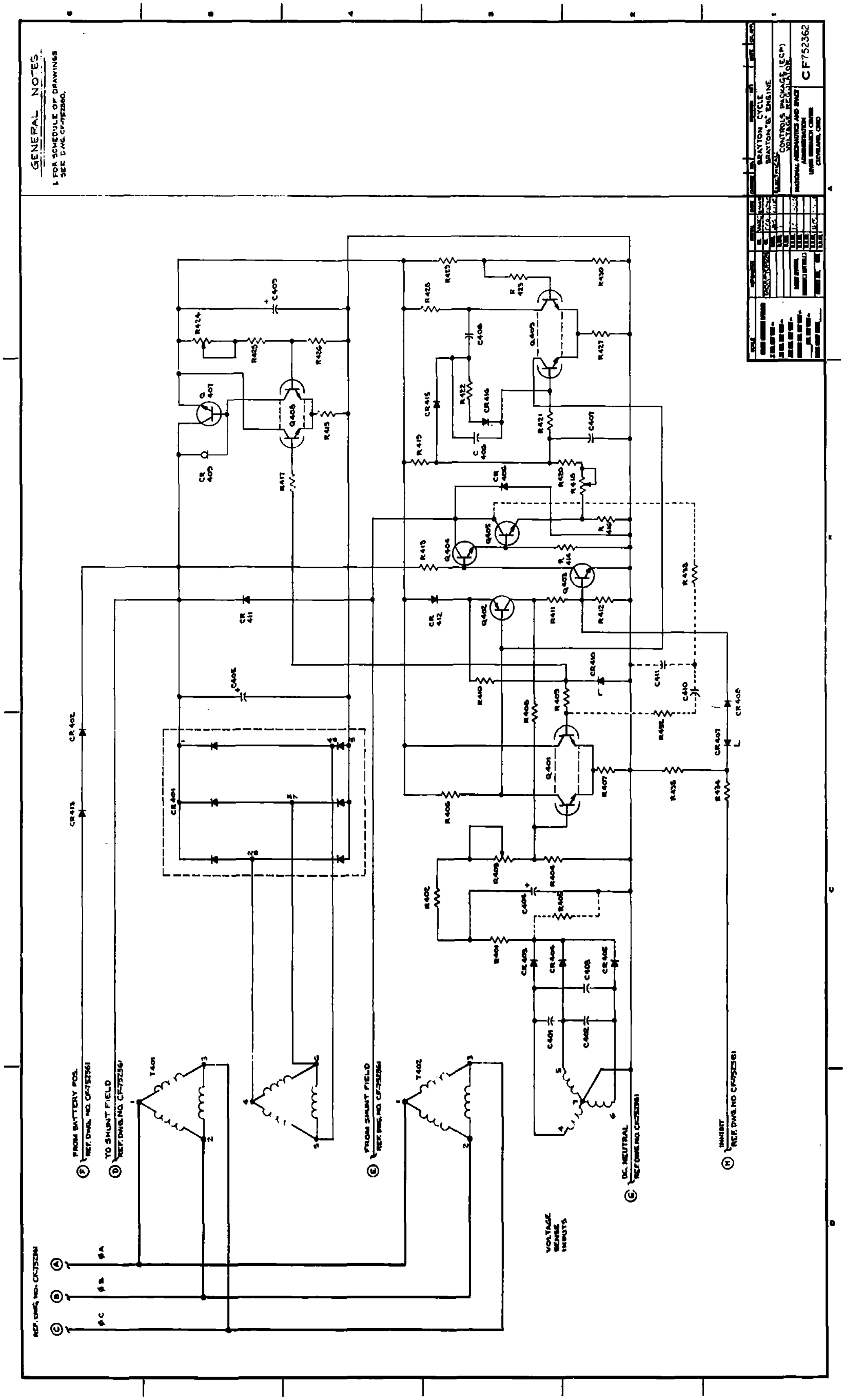
COMPONENT	POWER DISSIPATED (WATTS)	t TO COLD PLATE (^{o}C)	% RATED POWER DISSIPATED AT MAXIMUM COLD PLATE TEMPERATURE
R408	.125	18	30%
R410	.063	16	28%
R411	.112	17	29%
R414	.020	10	10%
Q401	.008	7	
R415	.04	11	17%
R417	.001	6	
R425	.031	8	20%
R426	.032	8	20%
Q408			
CR409	.087	22	15%
R419	.055	17	22%
R420	.017	12	6%
R427	.018	10	12%
R428	.018	10	12%
R429	.045	16	18%
R430	.030	14	12%
CR413	3.5	14	23%
CR402	3.5	14	23%
CR506	1.67	25	
Q105 thru	9	29.3	65%
Q306C		(Δt Junct)	
Q405	15.3	50	30%
CR507	12	39	33%
R510 thru R513	15.2	15	
R416	2.4	8	37%
T101, 201, 301	.75	5	
L102A thru L302C	1.5	5	
AR101, 201, 301	.25	10	
AR102, 202, 302	.75	19	
AR103A thru 303C	.75	8	

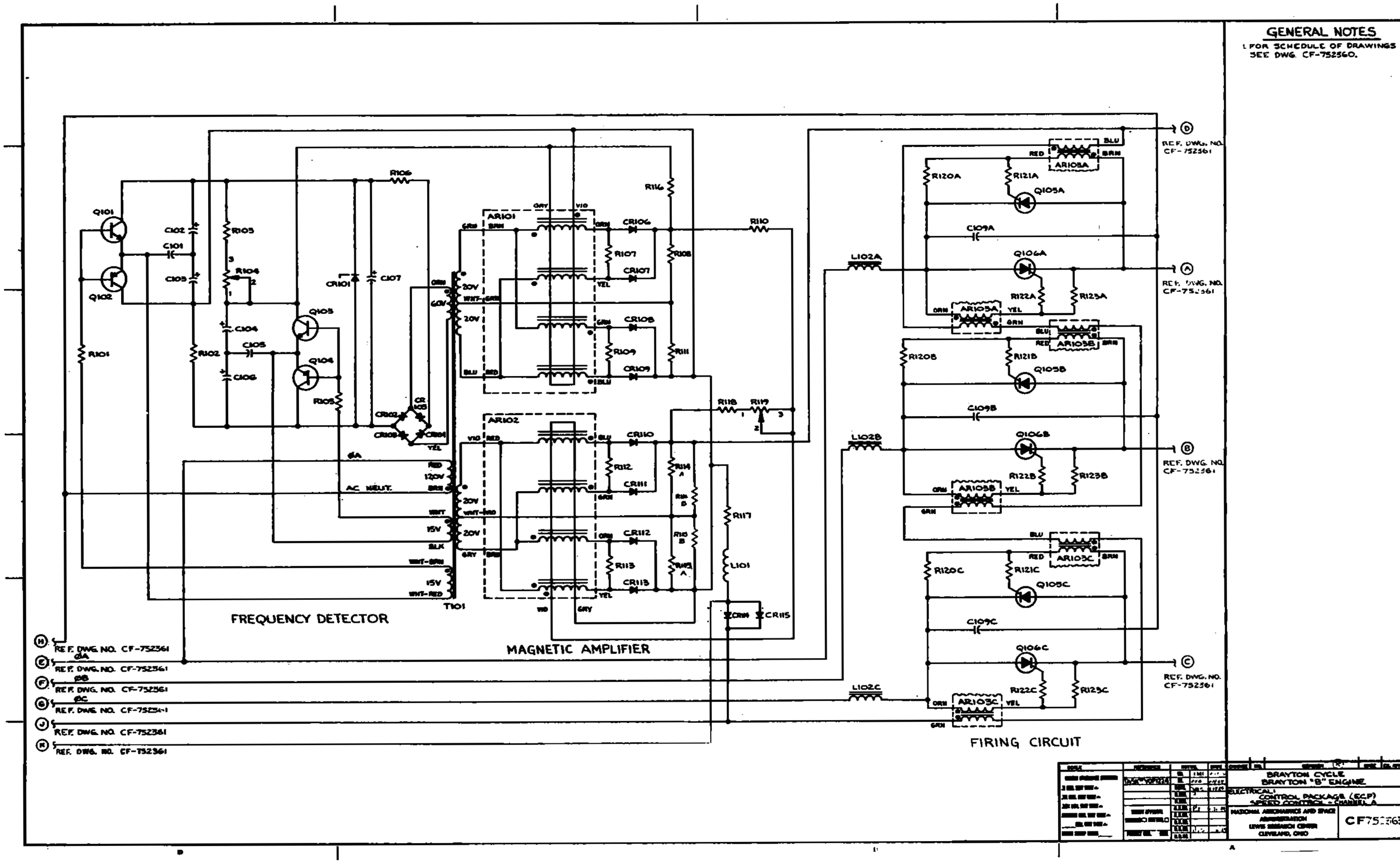
TABLE III

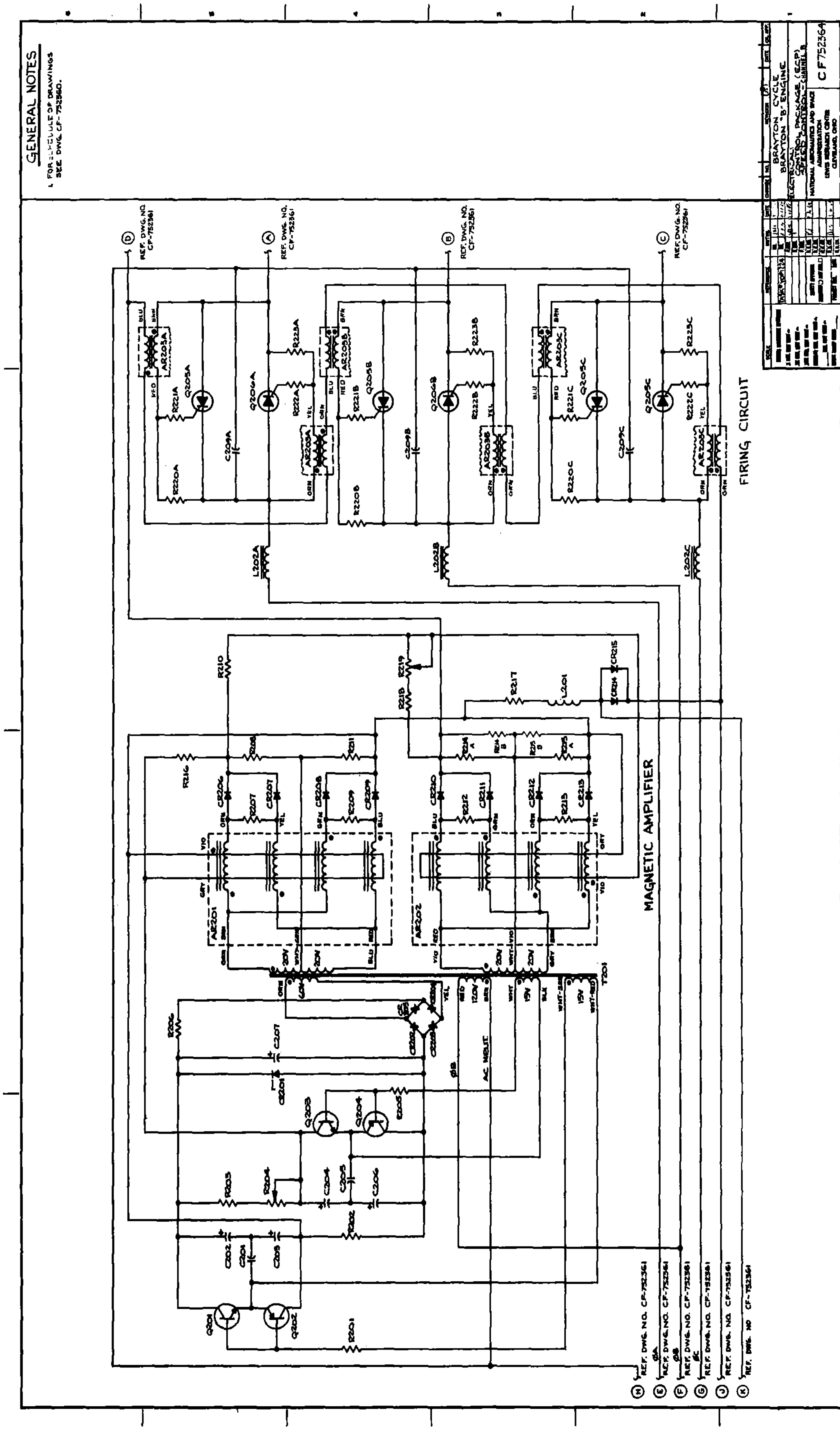
THERMOCOUPLE INSTALLATION

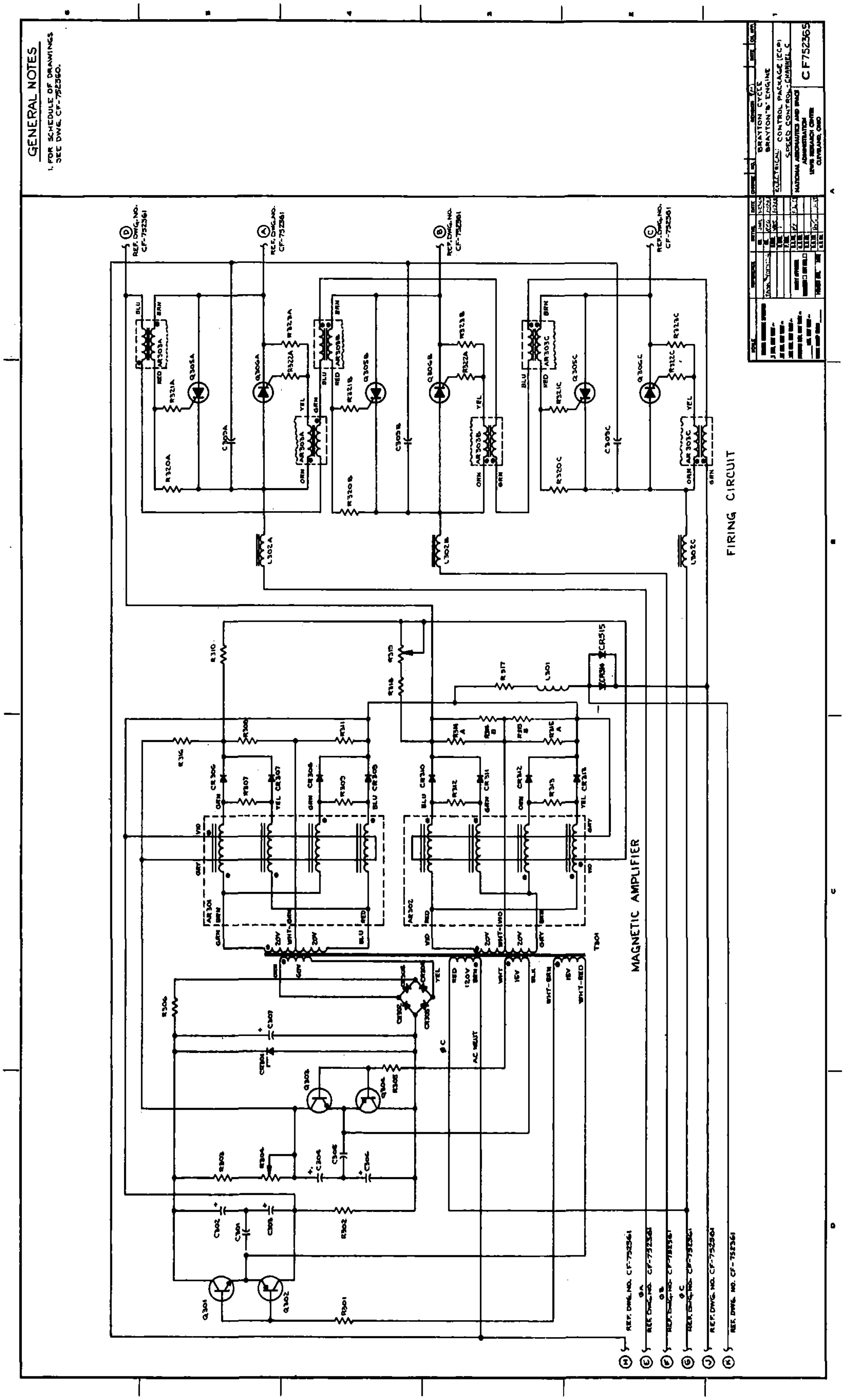
THERMOCOUPLE LOCATION	CONNECTOR TERMINATIONS	
Base Measurement #1	IRON	J3-M
(Near Q105B and Q106B)	Constantan	J3-N
Base Measurement #2	IRON	J3-P
(Near R510, R511)	Constantan	J3-R
Base Measurement #3	IRON	J3-S
(Near Q404, Q405)	Constantan	J3-T
Case Q105A	IRON	J4-A
	Constantan	J4-B
Case CR506	IRON	J4-C
	Constantan	J4-D
Case C109A	IRON	J4-E
	Constantan	J4-F
Case Q405	IRON	J-4G
	Constantan	J4-H
Case K503	IRON	J4-J
	Constantan	J4-K
Outer Covering, AR103A	IRON	J4-L
	Constantan	J4-M

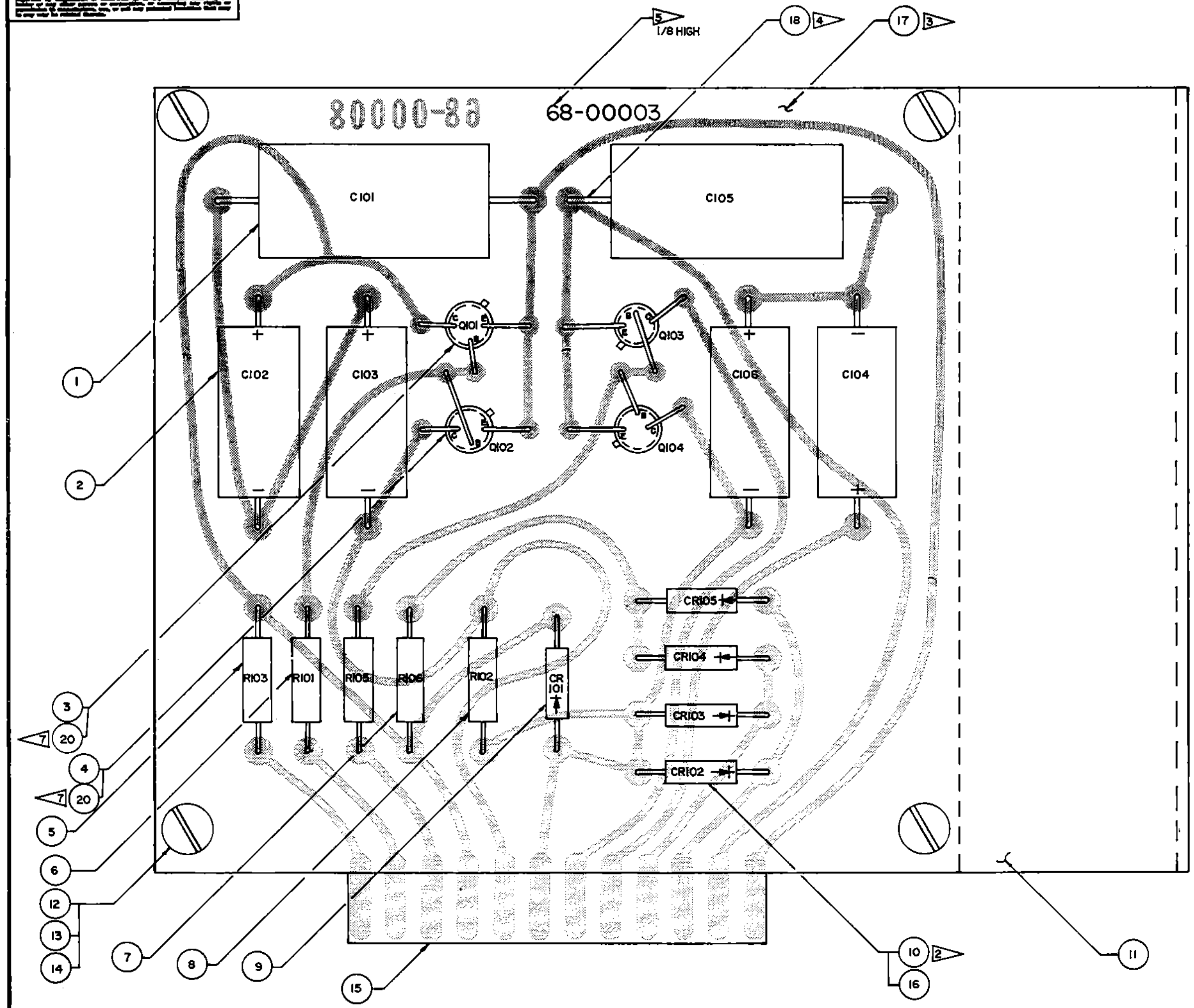

GENERAL NOTES
1. FOR SCHEDULE OF DRAWINGS SEE DRAWING CF752360.
2. COILS K501 - K502 X1, X2 WAS LAST ENERGIZED, (AS SHOWN).
3. COILS K503 - K504 Y1, Y2 WAS LAST ENERGIZED, (AS SHOWN).
VOLTAGE REGULATOR SEE DWG. CF752362
SPEED CONTROL-CHANNEL A SEE DWG. CF752363
SPEED CONTROL-CHANNEL B SEE DWG. CF752364
SPEED CONTROL-CHANNEL C SEE DWG. CF752365
THERMOCOUPLES FOR BASE PLATE TEMPERATURES
THERMOCOUPLES FOR DEVELOPMENT TESTING
MS 3122-E-14-19P
MS 3122-E-18-32P
MS 3122-E-16-26P
CHASSIS GROUND
DC COMMON
BRAYTON CYCLE
BRAYTON "B" ENGINE
ELECTRICAL CONTROLS PACKAGE (ECP) ASSEMBLY
CF752361


GENERAL NOTES
1. FOR SCHEDULE OF DRAWINGS SEE DWG. CF-752360.
BRAYTON CYCLE
BRAYTON "B" ENGINE
CONTROLS PACKAGE (ECP) VOLTAGE REGULATOR
CF752362
FROM BATTERY POS.
TO SHUNT FIELD
FROM SHUNT FIELD
DC NEUTRAL
INHIBIT
VOLTAGE SENSE INPUTS


GENERAL NOTES
1. FOR SCHEDULE OF DRAWINGS SEE DWG. CF-752560.
FREQUENCY DETECTOR
MAGNETIC AMPLIFIER
FIRING CIRCUIT
T101
AR101
AR102
AC NEUT.
REF. DWG. NO. CF-752361
BRAYTON CYCLE
BRAYTON "B" ENGINE
ELECTRICAL
CONTROL PACKAGE (ECP)
SPEED CONTROL - CHANNEL A
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
CLEVELAND, OHIO
CF752563


GENERAL NOTES
MAGNETIC AMPLIFIER
FIRING CIRCUIT
BRAYTON CYCLE
BRAYTON "B" ENGINE
CF75236A


GENERAL NOTES
1. FOR SCHEDULE OF DRAWINGS SEE DWG. CF-752360.
MAGNETIC AMPLIFIER
FIRING CIRCUIT
BRAYTON CYCLE
BRAYTON "B" ENGINE
ELECTRICAL: CONTROL PACKAGE (ECP)
SPEED CONTROL - CHANNEL C
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
CLEVELAND, OHIO
CF752365



NOTES—

1. PRINTED WIRING ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER MSFC-PROC-256, SOLDER PER NPC-200-4.
2. BOND COMPONENTS EXCEPT GLASS OR GLASS COATED COMPONENTS TO HEATSINK PER KSC-SPEC-E-0001.
3. CONFORMAL COAT BOTH SIDES OF BOARD EXCEPT CONNECTOR PINS PER KSC-SPEC-E-0001.
4. COVER ALL COMPONENT LEADS WITH CLEAR PVC TUBING PER MIL-I-7444.
5. INK STAMP PART NO. PER MIL-STD-130.
6. REFERENCE DRAWINGS:
   PRINTED WIRING MASTER 68-00008
   PRINTED WIRING BOARD 68-00007
   SCHEMATIC 68-00004
7. CUT INSULATOR TO FIT DIA. OF TRANSISTOR.

CIRCUIT COMPONENT LIST

FIND NO.	CIRCUIT COMPONENT	NO. REQ	DESCRIPTION	MIL SPEC. OR MFG. NAME	MIL TYPE OR MFG PART NUMBER
1	C101, C105	2	CAPACITOR (GFE)	G.E.	74F01BA105
2	C102,C103,C104,C106	4	CAPACITOR	SPRAGUE	350D156X9075S2
3	Q101, Q103	2	TRANSISTOR	TEXAS INST.	2N2222A
4	Q102,Q104	2	TRANSISTOR	TEXAS INST.	2N2907A
5	R103	1	RESISTOR / 620Ω	DALE	AGS-5-620
6	R101,R105	2	RESISTOR / 2.2K	OHMITE	RC20GF222J
7	R106	1	RESISTOR / 150Ω	DALE	AGS-5-150
8	R102	1	RESISTOR / 820Ω	DALE	AGS-5-820
9	CR101	1	DIODE	MOTOROLA	IN978B
10	CR102,103,104,105	4	DIODE (GFE)	TRW	IN4858
11		1	HEAT SINK	HAYES INT.	68-00005
12		4	SCREW		AN508-4-6
13		4	NUT		MS20365-440
14		8	WASHER		AN960D4L
15		1	CIRCUIT BOARD	HAYES INT.	68-00007
16		AR	EPOXY	ARMSTRONG	X-81
17		AR	CONFORMAL COATING	COAST PRO-SEAL	CPS773
18		AR	PVC TUBING, CLEAR		
19		AR	SOLDER, S/N 60		
20	(FOR Q101,102,103,104)	4	INSULATOR, MYLAR .03THK	7	

REVISIONS: A — INCORPORATED EO 1 & 2

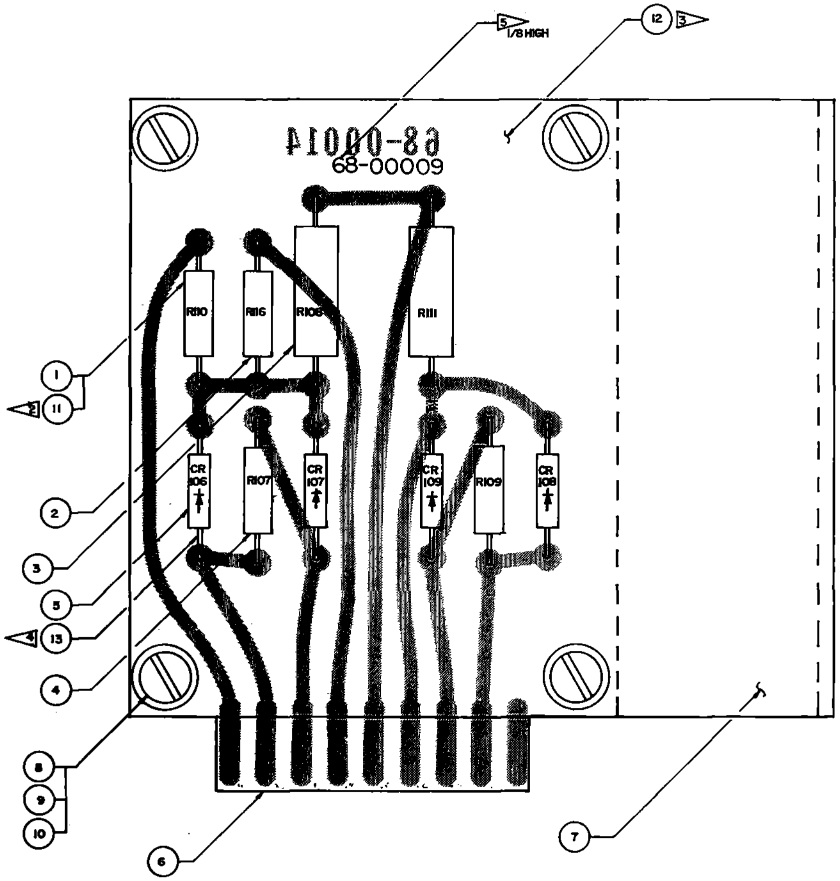
ORIGINAL DATE OF DRAWING 20 AUG 68
DRAWN B. WEAVER
CHECK SC

HAYES INTERNATIONAL CORPORATION
BIRMINGHAM, ALABAMA

PRINTED WIRING ASSY
FREQ. DET. CH. A
BRAYTON "B" ELECT. PACKAGE

SIZE | CODE IDENT NO. 91763 | 68-00003
CONTRACT NO. NAS3-11784
SCALE 4/1 | WEIGHT | SHEET 1 OF 1

SEE ENGINEERING RECORDS
UNLESS OTHERWISE SPECIFIED
NEXT ASSY | USED ON
APPLICATION



PART No.		ZONE	SYM	DESCRIPTION	DATE	APPROVAL
			A	INCORPORATED ECO 1 & 2	1-13-69	SC

NOTES—

1. PRINTED WIRING ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER MSFC-PROC-256, SOLDER PER NPC-200-4.
2. BOND COMPONENTS EXCEPT GLASS OR GLASS COATED COMPONENTS TO HEATSINK PER KSC-SPEC-E-0001.
3. CONFORMAL COAT BOTH SIDES OF BOARD EXCEPT CONNECTOR PINS PER KSC-SPEC-E-0001.
4. COVER ALL COMPONENT LEADS WITH CLEAR PVC TUBING PER MIL-I-7444.
5. INK STAMP PART NO. PER MIL-STD-130.
6. REFERENCE DRAWINGS:
   PRINTED WIRING MASTER 68-00014
   PRINTED WIRING BOARD 68-00013
   SCHEMATIC 68-00010

CIRCUIT COMPONENT LIST

FIND NO.	CIRCUIT COMPONENT	NO. REQ	DESCRIPTION	MIL SPEC. OR MFG. NAME	MIL TYPE OR MFG PART NUMBER
1	R110,	1	RESISTOR / 5.1K (GFE)	OHMITE	RC20GF512J
2	R116	1	RESISTOR / 11 K	ANGSTROM	RN60E1102F
3	R108, R111	2	RESISTOR / 470Ω	DALE	AGS-5-470
4	R107, R109	2	RESISTOR / 82K	ANGSTROM	RN60E8252F
5	CR106, CR107, CR108, CR109	4	DIODE (GFE)	TRW	IN485B
6		1	CIRCUIT BOARD	HAYES INT.	68-00013
7		1	HEAT SINK	HAYES INT.	68-00011
8		4	SCREW		AN508-4-6
9		4	NUT		MS20365-440
10		8	WASHER		AN960D4L
11		AR	EPOXY	ARMSTRONG	X-81
12		AR	CONFORMAL COATING	COAST PRO-SEAL	CPS773
13		AR	PVC TUBING, CLEAR		
14		AR	SOLDER, S/N60		

SEE ENGINEERING RECORDS

NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES
MATERIAL
HEAT TREATMENT
FINAL PROTECTIVE FINISH

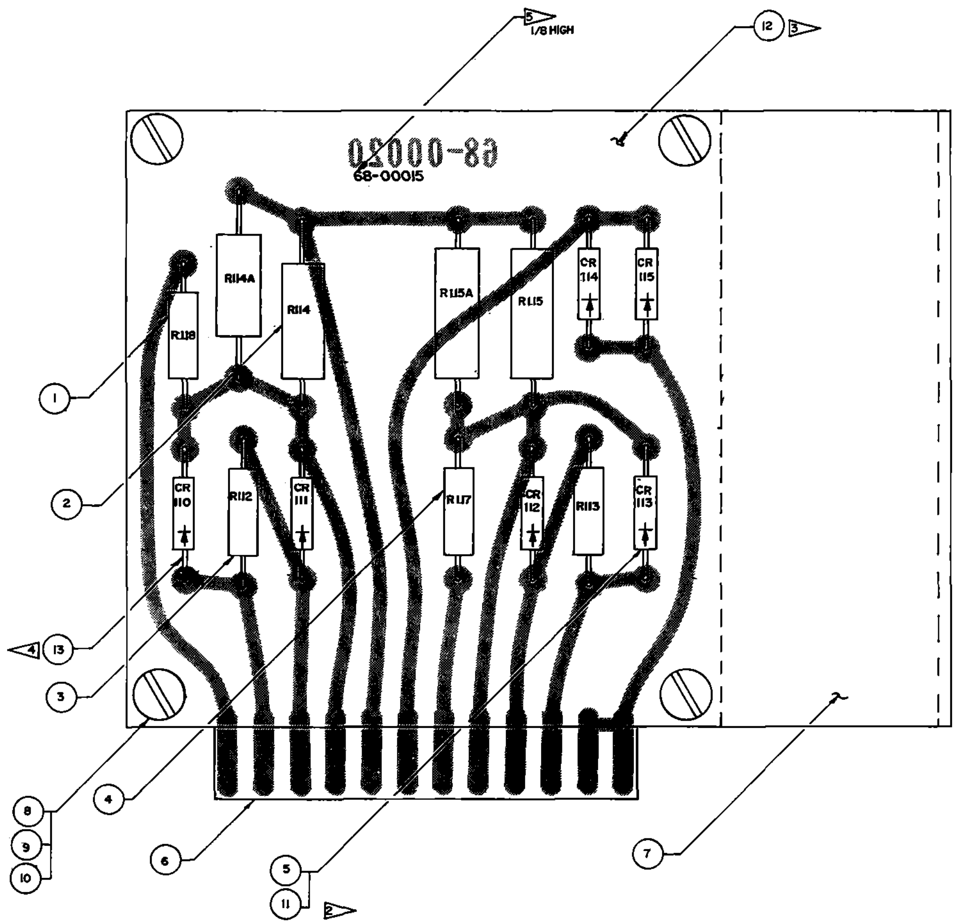
ORIGINAL DATE OF DRAWING 20 AUG 68
DRAWN B. WEAVER
CHECK SC
ENGINEER B. B. Weaver 8-25-68
APPROVED 8-30-68
APPROVED 8-30-68
CUSTOMER APPROVAL
CONTRACT NO. NAS3-11784

HAYES INTERNATIONAL CORPORATION
BIRMINGHAM, ALABAMA

PRINTED WIRING ASSY
MAGNETIC AMP. NO.1 CH. A
BRAYTON "B" ELECT. PACKAGE

SIZE D | CODE IDENT NO. 91763 | 68-00009
SCALE 4/1 | WEIGHT | SHEET 1 OF 1

PART No.		ZONE	SYM	DESCRIPTION	DATE	APPROVAL
			A	INCORPORATED EO 1,3 & 8	1-15-69	SC



NOTES—

1. PRINTED WIRING ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER MSFC-PROC-256, SOLDER PER NPC-200-4.
2. BOND COMPONENTS EXCEPT GLASS OR GLASS COATED COMPONENTS TO HEATSINK PER KSC-SPEC-E-0001.
3. CONFORMAL COAT BOTH SIDES OF BOARD EXCEPT CONNECTOR PINS PER KSC-SPEC-E-0001.
4. COVER ALL COMPONENT LEADS WITH CLEAR PVC TUBING PER MIL-I-7444.
5. INK STAMP PART NO. PER MIL-STD-130.
6. REFERENCE DRAWINGS:
   PRINTED WIRING MASTER 68-00020
   PRINTED WIRING BOARD 68-00019
   SCHEMATIC 68-00016

CIRCUIT COMPONENT LIST

FIND NO.	CIRCUIT COMPONENT	NO. REQ	DESCRIPTION	MIL. SPEC. OR MFG. NAME	MIL TYPE OR MFG PART NUMBER
1	R118	1	RESISTOR / 4300 Ω GFE	OHMITE	RC20GF432J
2	R114, R114A, R115, R115A	4	RESISTOR / 200 Ω	DALE	RS-2B
3	R112 R113	2	RESISTOR / 82K	ANGSTROM	RN60E8252F
4	R117	1	RESISTOR / 1200 Ω	OHMITE	RC20GF122J
5	CR110 THRU CR115	6	DIODE GFE	TRW	IN485B
6		1	CIRCUIT BOARD	HAYES INT.	68-00019
7		1	HEAT SINK	HAYES INT.	68-00017
8		4	SCREW		AN508-4-6
9		4	NUT		MS20365-440
10		8	WASHER		AN960D4L
11		AR	EPOXY	ARMSTRONG	X-81
12		AR	CONFORMAL COATING	COAST PRO-SEAL	CPS 773
13		AR	PVC TUBING, CLEAR		
14		AR	SOLDER, S/N 60		

SEE ENGINEERING RECORDS

NEXT ASSY | USED ON | APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES
MATERIAL
HEAT TREATMENT
FINAL PROTECTIVE FINISH

ORIGINAL DATE OF DRAWING 22 AUG 68
DRAWN B. WEAVER
CHECK
CONTRACT NO. NAS3-11784

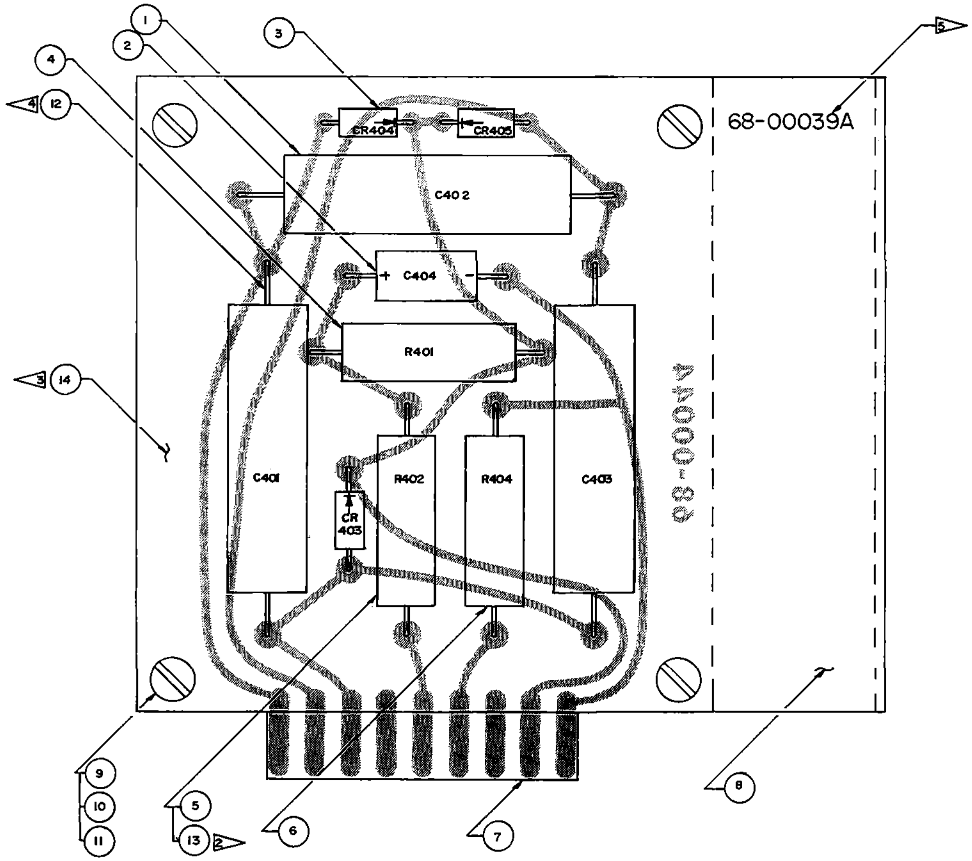
HAYES INTERNATIONAL CORPORATION
BIRMINGHAM, ALABAMA

PRINTED WIRING ASSY.
MAGNETIC AMP. NO. 2 CH. A
BRAYTON "B" ELECT. PACKAGE

SIZE D | CODE IDENT NO. | 68-00015

SCALE 4/1 | WEIGHT | SHEET 1 OF 1

PART No.		ZONE	LTR	DESCRIPTION	DATE	APPROVAL
			A	REVISED & REDRAWN		



NOTES

1. PRINTED WIRING ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER MSFC-PROC-256, SOLDER PER NPC-200-4.
2. BOND COMPONENTS EXCEPT GLASS OR GLASS COATED COMPONENTS TO HEATSINK PER KSC-SPEC-E-0001.
3. CONFORMAL COAT BOTH SIDES OF BOARD EXCEPT CONNECTOR PINS PER KSC-SPEC-E-0001.
4. COVER ALL COMPONENT LEADS WITH CLEAR PVC TUBING PER MIL-I-7444.
5. INK STAMP PART NO. PER MIL-STD-130.
6. REFERENCE DRAWINGS:
   PRINTED WIRING MASTER 68-00044
   PRINTED WIRING BOARD 68-00043
   SCHEMATIC 68-00040

CIRCUIT COMPONENT LIST

FIND NO	CIRCUIT COMPONENT	NO REQD	DESCRIPTION	MIL SPEC OR MFG NAME	MIL TYPE OR MFG PART NUMBER
1	C401,C402,C403	3	CAPACITOR (GFE)	SPRAGUE	196P10492S4
2	C404	1	CAPACITOR	SPRAGUE	150D105X9075B2
3	CR403,CR404,CR405	3	DIODE	T. R. W.	IN485B
4	R401	1	RESISTOR, 698 Ω	SPRAGUE	RB54CE698ROF
5	R402	1	RESISTOR, 1500 Ω	SPRAGUE	RB54CE1500OF
6	R404	1	RESISTOR, 750 Ω (GFE)	SPRAGUE	RB54CE750ROF
7		1	CIRCUIT BOARD	HAYES INT.	68-00043A
8		1	HEAT SINK	HAYES INT.	68-00041A
9		4	SCREW		AN508-4-8
10		4	NUT		MS20365-440
11		8	WASHER		AN960D4L
12		AR	TUBING, PVC, CLEAR		
13		AR	EPOXY	ARMSTRONG	X-81
14		AR	CONFORMAL COATING	COAST PRO-SEAL	CPS773
15		AR	SOLDER, S/N60		

SEE ENGINEERING RECORDS

NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES

MATERIAL

HEAT TREATMENT

FINAL PROTECTIVE FINISH

ORIGINAL DATE OF DRAWING: 10 DEC 68
DRAWN: B. WEAVER
CHECK
ENGINEER
APPROVED
APPROVED
CUSTOMER APPROVAL
CONTRACT NO. NAS3-11784

HAYES INTERNATIONAL CORPORATION
BIRMINGHAM, ALABAMA

PRINTED WIRING ASSY
VOLTAGE SENS BOARD
BRAYTON "B" ELECT. PACKAGE

SIZE D | CODE IDENT NO. 91763 | 68-00039

SCALE 4/1 | WEIGHT | SHEET 1 OF 1

ZONE	SYM	REVISIONS DESCRIPTION	DATE	APPROVAL
	A	INCORPORATED EO 1 & 2	1-17-69	SC
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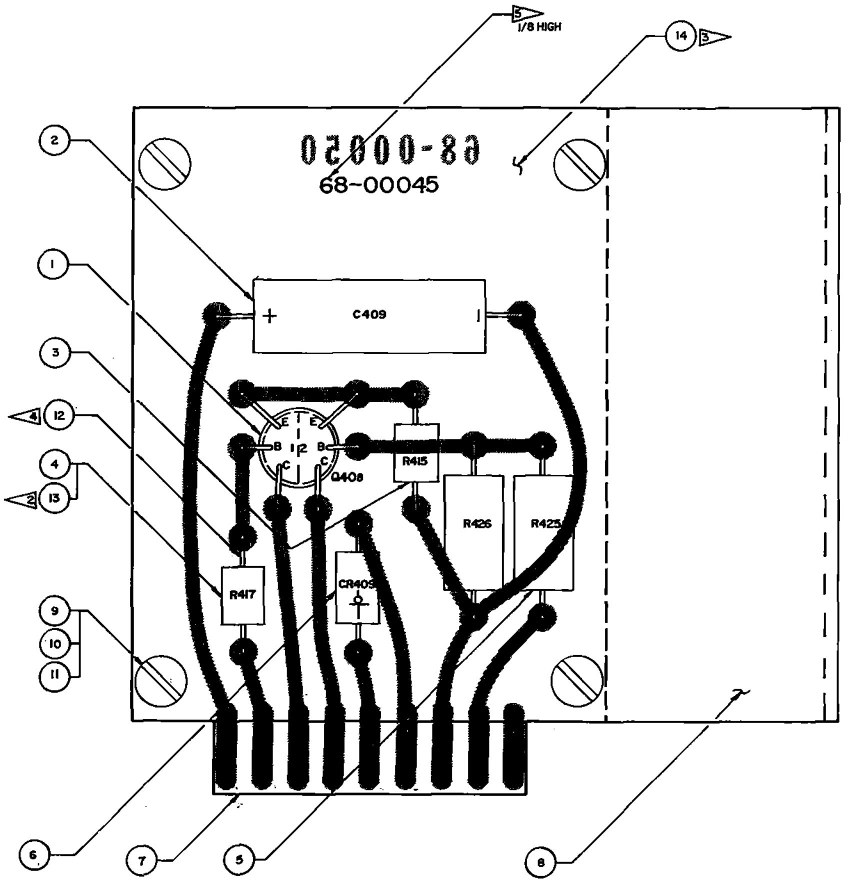


NOTES—

1. PRINTED WIRING ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER MSFC-PROC-256, SOLDER PER NPO-200-4.
2. BOND COMPONENTS EXCEPT GLASS OR GLASS COATED COMPONENTS TO HEATSINK PER KSC-SPEC-E-0001.
3. CONFORMAL COAT BOTH SIDES OF BOARD EXCEPT CONNECTOR PINS PER KSC-SPEC-E-0001.
4. COVER ALL COMPONENT LEADS WITH CLEAR PVC TUBING PER MIL-I-7444.
5. INK STAMP PART NO. PER MIL-STD-130.
6. REFERENCE DRAWINGS:
   - PRINTED WIRING MASTER 68-00050
   - PRINTED WIRING BOARD 68-00049
   - SCHEMATIC 68-00046

CIRCUIT COMPONENT LIST

FIND NO.	CIRCUIT COMPONENT	NO. REQ.	DESCRIPTION	MIL SPEC. OR MFG. NAME	MIL TYPE OR MFG PART NUMBER
1	Q408	1	TRANSISTOR (GFE)	T.I.	2N2060
2	C409	1	CAPACITOR	SPRAGUE	137D94UFXO
3	R415	1	RESISTOR / 820 Ω	C.G.	RL07S821G
4	R417	1	RESISTOR / 750 Ω	C.G.	RL07S751G
5	R425, R426	2	RESISTOR / 1210 Ω	SPRAGUE	RB55CE1210OF
6	CR409	1	DIODE (GFE)	MOTOROLA	IN5308
7		1	CIRCUIT BOARD	HAYES INT.	68-00049
8		1	HEAT SINK	HAYES INT.	68-00047
9		4	SCREW		AN508-4-6
10		4	NUT		MS20365-440
11		8	WASHER		AN960D4L
12		AR	TUBING, P.V.C., CLEAR		
13		AR	EPOXY	ARMSTRONG	X-81
14		AR	CONFORMAL COATING	COAST PRO-SEAL	CPS773
15		AR	SOLDER, S/N60		

SEE ENGINEERING RECORDS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES

MATERIAL

HEAT TREATMENT

FINAL PROTECTIVE FINISH

NEXT ASSY | USED ON

APPLICATION

ORIGINAL DATE OF DRAWING 22 AUG 68

DRAWN B.WEAVER

CHECK SC

CONTRACT NO. NAS3-11784

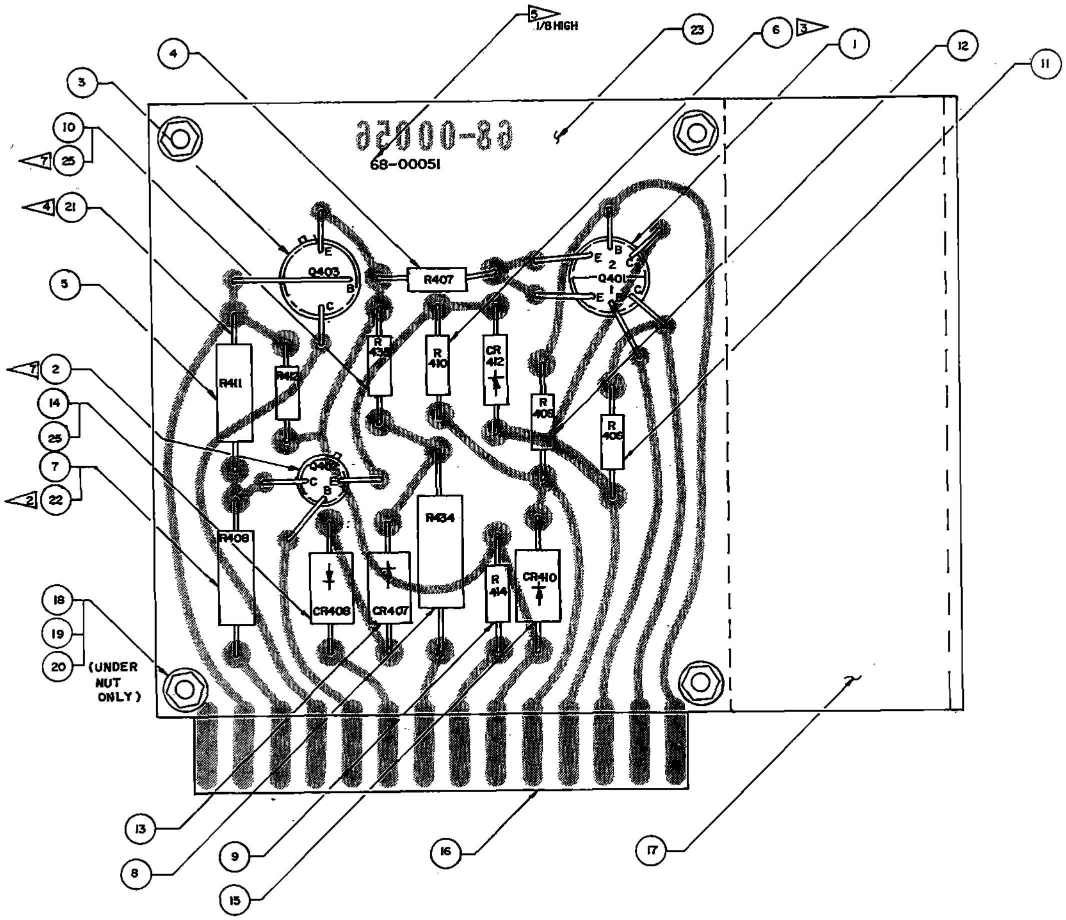
HAYES INTERNATIONAL CORPORATION

BIRMINGHAM, ALABAMA

PRINTED WIRING ASSY. REFERENCE VOLTAGE BD. BRAYTON "B" ELECT. PACKAGE

SIZE D | CODE IDENT NO. 91763 | 68-00045

SCALE 4/1 | WEIGHT | SHEET 1 OF 1



PART No.		REVISIONS				
	ZONE	SYM	DESCRIPTION	DATE	APPROVAL
		A	INCORPORATED EO 1,2,&3	1-9-69	E.C.

NOTES—

1. PRINTED WIRING ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER MSFC-PROC-256, SOLDER PER NPC-200-4.
2. BOND COMPONENTS EXCEPT GLASS OR GLASS COATED COMPONENTS TO HEATSINK PER KSC-SPEC-E-0001.
3. CONFORMAL COAT BOTH SIDES OF BOARD EXCEPT CONNECTOR PINS PER KSC-SPEC-E-0001.
4. COVER ALL COMPONENT LEADS WITH CLEAR PVC TUBING PER MIL-I-7444.
5. INK STAMP PART NO. PER MIL-STD-130.
6. REFERENCE DRAWINGS:
   PRINTED WIRING MASTER 68-00056
   PRINTED WIRING BOARD 68-00055
   SCHEMATIC 68-00052
7. CUT INSULATOR TO FIT DIA. OF TRANSISTORS.

CIRCUIT COMPONENT LIST

FIND NO.	CIRCUIT COMPONENT	NO. REQ	DESCRIPTION	MIL SPEC. OR MFG. NAME	MIL TYPE OR MFG PART NUMBER
1	Q401	1	TRANSISTOR GFE	T.I.	2N2060
2	Q402	1	TRANSISTOR	MOTOROLA	2N3251
3	Q403	1	TRANSISTOR	MOTOROLA	2N2219
4	R407	1	RESISTOR / 5600 Ω	C.G.	RL07S562G
5	R411	1	RESISTOR / 1600 Ω	C.G.	RL20S162G
6	R410, R412	2	RESISTOR / 1000 Ω	C.G.	RL07S102G
7	R408	1	RESISTOR / 470K	C.G.	RL20S474G
8	R434	1	RESISTOR / 1500 Ω	SPRAGUE	RW69V152
9	R414	1	RESISTOR / 100 Ω	C.G.	RL07S101G
10	R435	1	RESISTOR / 2000 Ω	C.G.	RL07S202G
11	R406	1	RESISTOR / 2700 Ω	C.G.	RL07S272G
12	R409	1	RESISTOR / 620 Ω	C.G.	RL07S621G
13	CR407	1	DIODE	MOTOROLA	IN753A
14	CR408, CR412	2	DIODE	T.R.W.	IN485B
15	CR410	1	DIODE GFE	MOTOROLA	IN827A
16		1	CIRCUIT BOARD	HAYES INT.	68-00056
17		1	HEAT SINK	HAYES INT.	68-00053
18		4	SCREW		AN508-4-6
19		4	NUT		MS20365-440
20		4	WASHER		AN960D4L
21		AR	P.V.C. TUBING, CLEAR		
22		AR	EPOXY	ARMSTRONG	X-81
23		AR	CONFORMAL COATING	COAST PRO-SEAL	CPS 773
24		AR	SOLDER, S/N60		
25	(FOR Q402, 403)	2	INSULATOR, MYLAR .03THK	7	

SEE ENGINEERING RECORDS

NEXT ASSY	USED ON
APPLICATION	

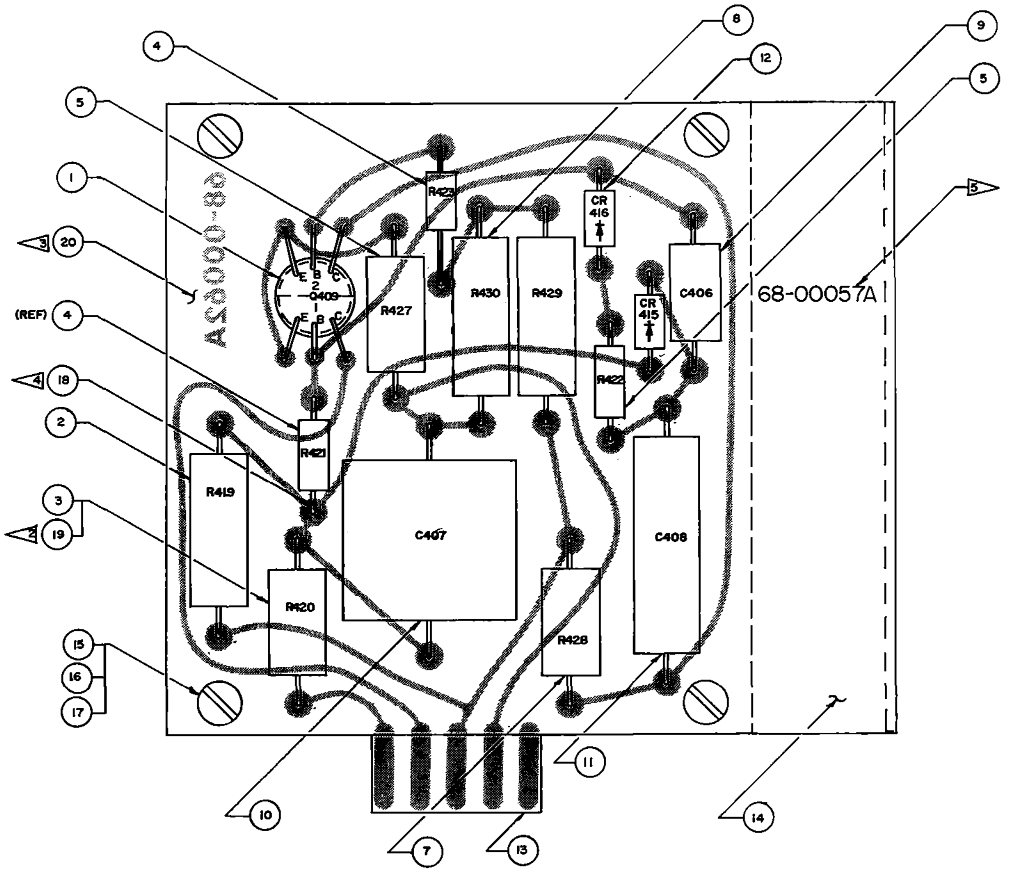
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES
MATERIAL
HEAT TREATMENT
FINAL PROTECTIVE FINISH

ORIGINAL DATE OF DRAWING 22 AUG 68
DRAWN B. WEAVER
CHECK E.C.
STRESS
ENGINEER B.L. Weaver 8-28-68
APPROVED 8-30-68
APPROVED 9-30-68
CUSTOMER APPROVAL
CONTRACT NO. NAS3-11784

HAYES INTERNATIONAL CORPORATION
BIRMINGHAM, ALABAMA

PRINTED WIRING ASSY
COMPARATOR BOARD
BRAYTON "B" ELECT. PACKAGE

SIZE D | CODE IDENT NO. 91763 | 68-00051
SCALE 4/1 | WEIGHT | SHEET 1 OF 1



NOTES—

1. PRINTED WIRING ASSEMBLY TO BE CONSTRUCTED AND INSPECTED PER MSFC-PROC-256, SOLDER PER NPC-200-4.
2. BOND COMPONENTS EXCEPT GLASS OR GLASS COATED COMPONENTS TO HEATSINK PER KSC-SPEC-E-0001.
3. CONFORMAL COAT BOTH SIDES OF BOARD EXCEPT CONNECTOR PINS PER KSC-SPEC-E-0001.
4. COVER ALL COMPONENT LEADS WITH CLEAR PVC TUBING PER MIL-I-7444.
5. INK STAMP PART NO. PER MIL-STD-130.
6. REFERENCE DRAWINGS:
   PRINTED WIRING MASTER 68-00062
   PRINTED WIRING BOARD 68-00061
   SCHEMATIC 68-00058

CIRCUIT COMPONENT LIST

FIND NO.	CIRCUIT COMPONENT	NO REQD	DESCRIPTION	MIL-SPEC OR MFG NAME	MIL-TYPE OR MFG PART NUMBER
1	Q409	1	TRANSISTOR (GFE)	T. I.	2N2060
2	R419, R429	2	RESISTOR / 1800 Ω	SPRAGUE	RB54CE18000B
3	R420	1	/ 562 Ω	SPRAGUE	RB55CE562R0F
4	R421, R423	2	/ 2200 Ω	C.G.	RL07S222G
5	R422	1	/ 3600 Ω	C.G.	RL07S362G
6	R427	1	/ 2000 Ω	SPRAGUE	RB55CE20000B
7	R428	1	/ 2710 Ω	SPRAGUE	RB55CE27100B
8	R430	1	RESISTOR/ 1210 Ω	SPRAGUE	RB54CE12100B
9	C406	1	CAPACITOR	C G	CY10C221F
10	C407	1	CAPACITOR	C G	CY30C103J
11	C408	1	CAPACITOR	SPRAGUE	196P22392S4
12	CR415, CR416	2	DIODE (GFE)	T. R. W.	1N485B
13		1	CIRCUIT BOARD	HAYES INT.	68-00061A
14		1	HEAT SINK	HAYES INT.	68-00059A
15		4	SCREW		AN508-4-6
16		4	NUT		MS20365-440
17		4	WASHER		AN960D4L
18		AR	TUBING, PVC, CLEAR		
19		AR	EPOXY	ARMSTRONG,	X81
20		AR	CONFORMAL COATING	COAST PRO-SEAL	CPS773
21		AR	SOLDER, S/N60		

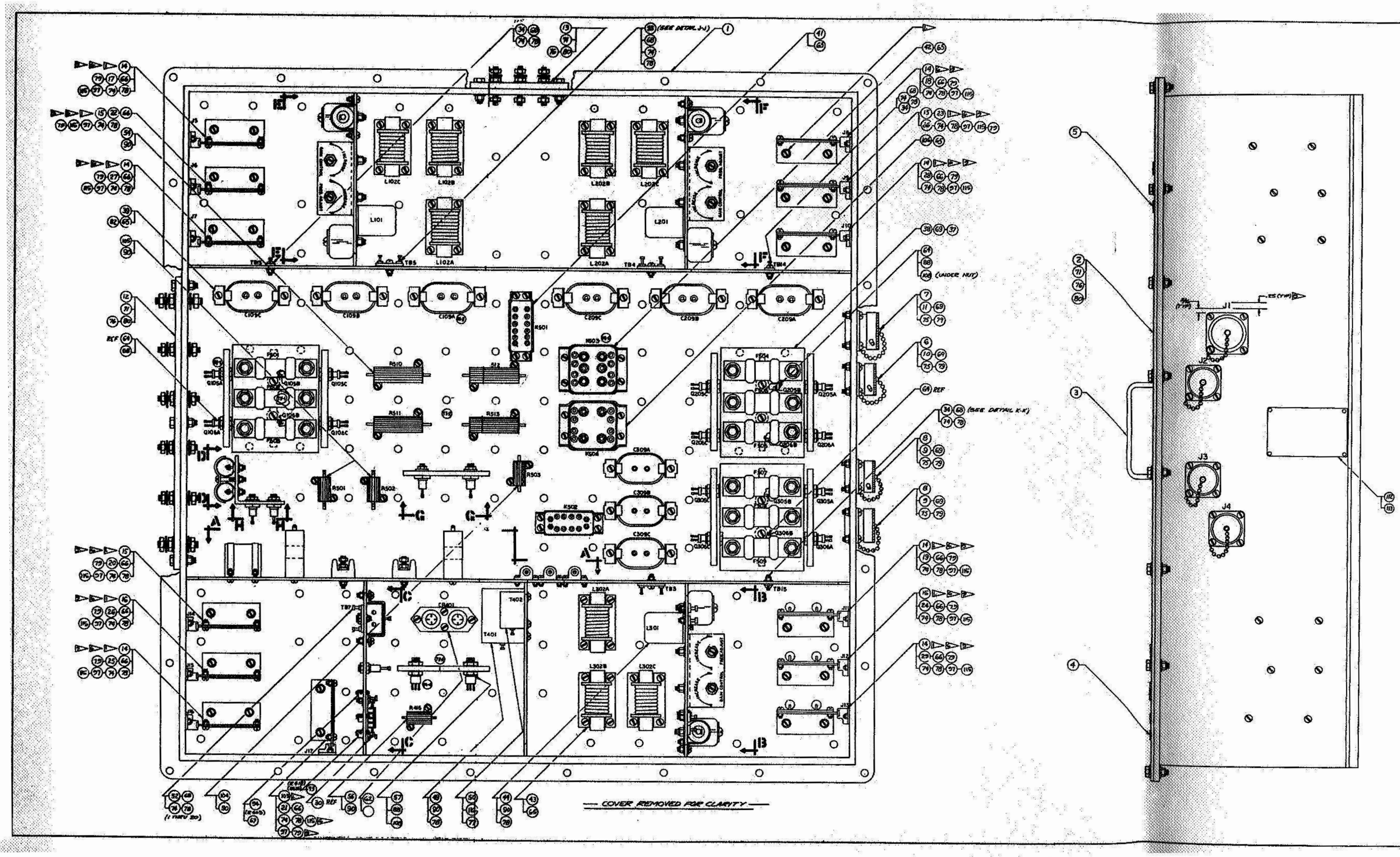
REVISIONS: A — REVISED & REDRAWN

HAYES INTERNATIONAL CORPORATION
BIRMINGHAM, ALABAMA

PRINTED WIRING ASSY
AMPLIFIER BOARD
BRAYTON "B" ELECT. PKG.

DRAWN: B. WEAVER
SEE ENGINEERING RECORDS
UNLESS OTHERWISE SPECIFIED
CONTRACT NO. NAS3-11784
SIZE D | CODE IDENT NO. | 68-00057
SCALE 4/1 | WEIGHT | SHEET 1 OF 1

REV	ZONE	LTR	DESCRIPTION	DATE	APPROVED
		A	INC. EO'S 1 THRU 24, ADDED FIND NO'S 103 THRU 117 TO L/M & F/D. ADDED NOTES 10 THRU 15.		



NOTES

1. MATCH DRILL BASE PER R.C. HEAT SINKS AT ASSY. DRILL AND TAP FOR 8-32 BOLT.
2. ASSEMBLE PER MSFC-PROC-256.
3. FOLD ALUM. FOIL .125 THICK FOR INSTALLATION UNDER ALL AR COMPONENTS
4. MARK COMPONENT REF DES ADJACENT TO ALL COMPONENTS NOT SHOWN.
5. SOLDER PER NPC-200-4.
6. DRILL SIDE WALL PER P.C. CONNECTOR & ASSY DRILL NO. 9/32 (.156) 2-HOLES PER CONNECTOR
7. GOVERNMENT FURNISHED EQUIPMENT.
8. SILKSCREEN PER MSFC-STD-372.
9. CONTACTS TO BE INSTALLED IN P.C. CONNECTORS PRIOR TO ASSY.
10. MATCH DRILL TERM. BOARD NO. 6 PER HOLE PATTERN IN 68-00002.
11. MAKE FROM 1533-33, USE (1) SECTION PER TERM BD.
12. ALL P.C. CONNECTORS WILL BE SOCKETED
13. TERM. BOARDS 6, 11 & 12 TO BE MADE FROM 1833-33 FIND NO. 33
14. MS35207-232 MAY BE SUBSTITUTED FOR FIND NO. 66.
15. (T-) INDICATES THERMOCOUPLE TERMINATIONS. BEADS SHALL BE BONDED IN PLACE, USING X-81 EPOXY. (SEE WIRE LIST 68-00066 FOR CONN. TERMINATIONS)

PART NUMBER	FIND NO.	QTY	CODE IDENT	NOMENCLATURE	MATERIAL	STOCK SIZE	MATL SPEC	HEAT TREAT	FINISH SPEC	UNIT WT
X-81	117	AR		EPOXY	ARMSTRONG					
AN520-4-4	116	4		SCREW						
AN508-8-6	115	26		SCREW						
	114	AR		LACING CORD						
MS21318-3	113	4		DRIVE SCREW						
	112	1		MFG. NAME PLATE						
MS24677-14	111	12		CAP SCREW						
RCE06F101J	110	18		RESISTOR		▷				
RC08FE11J	109	18		RESISTOR		▷				
DF68	108	23		MICA WASHER	RCA					
DF6C	107	11		MICA WASHER	RCA					
H-407	106	1		CONTACTOR	HARTMAN					
3825-.636Ω	105	2		RESISTOR	SAGE	▷				
3225-.140Ω	104	1		RESISTOR	SAGE	▷				
582885-3	103	1		CONNECTOR	AMP					
	102	AR		WIRE	8 AWG PER MCN-5086 TYPE I - COLOR WHITE					
	101	AR		WIRE	12 AWG PER MCN-5086 TYPE I - COLOR WHITE					
	100	AR		WIRE	16 AWG PER MIL-W-16878/1 TYPE B - COLOR WHITE					
	99	AR		WIRE	18 AWG PER MIL-W-16878/1 TYPE B - COLOR WHITE					
	98	AR		WIRE	20 AWG PER MIL-W-16878/1 TYPE B - COLOR WHITE					
60815-4	97	150		CONTACT, CONN.	AMP	▷				
	96	AR		ALUM. FOIL	.005 THK.	▷				
5905	95	1		CLIP	OHMIT					
224L-500-102	94	1		POT	BOURNS	▷				
224L-640-102	93	2		POT	BOURNS	▷				
3500S-1-501	92	3		POT	BOURNS	▷				
CLU1631	91	5		POT	OHMITE	▷				
AN508-6-6	90	22		SCREW						
15564	89	11		WASHER	NATIONAL	BERYLLIA	CORP.			
15955	79	23		WASHER	NATIONAL	BERYLLIA	CORP.			
68-00067-6	87	6		BRACKET						
-2	86	3								
-3	85	1								
-5	84	1								
68-00067-4	83	3		BRACKET						
302C920 P178	82	18		CLAMP	G.E.					
14008	81	19		TERM PT.	USECO					
AN960D-10L	80	84		WASHER						
-8L	79	50								
-6L	78	128								
AN960D-4L	77	10		WASHER						
MS20365-1032	76	38		NUT						
MS20365-832	75	24		NUT						
MS20365-632	74	93		NUT						
AN970-4	73	15		WASHER						
MS20365-440	72	6		NUT						
AN3-7	71	38		BOLT						
AN508-10-24	70	15		SCREW						
-8-12	69	24								
-6-5	68	33								
AN508-4-11	67	6		SCREW						
AN508-6-10	66	60		SCREW		▷				
AN508-8-6	65	66		SCREW						
C35M	64	18		DIODE	G.E.	▷				
1N1206	63	4		DIODE	G.E.	▷				
45524-200	62	1		DIODE	VARO.	▷				
1N1206	61	1		DIODE	T.I.	▷				
1N4549A	60	1		DIODE	T.I.					
1N4552A	59	1		DIODE	T.I.					
1N4507	58	6		DIODE	G.E.					
521246-1	57	3		TRANSISTOR	AIRESERCH					
RE70NR200	56	1		RESISTOR	DALE					
RWG7V511	55	1		RESISTOR	SPRAGUE					
3550 M-22.1Ω	54	4		RESISTOR	SAGE					
3225 M-2Ω	53	6		RESISTOR	SAGE					
521247-1	52	3		TRANSFORMER	AIRESERCH					
HE 99-3	51	6		TRANSFORMER	AIRESERCH					
521260A	50	1		TRANSFORMER	AIRESERCH					
521259B	49	16		TRANSFORMER	AIRESERCH					
69F116442	48	1		CAPACITOR	G.E.					
XTH256U180P0C	47	3		CAPACITOR	MALLORY					
307597-1	46	9		SAT. REA	AIRESERCH					
307595-1	45	6		SAT. REA	AIRESERCH					
MQA9	44	3		COIL	UTC					
307596	43	9		COIL	AIRESERCH					
H-405	42	1		CONTACTOR	HARTMAN					
H-203	41	2		CONTACTOR	HARTMAN					
HC4-106-5	40	2		CAPACITOR	MARSHALL					
28F956	39	9		CAPACITOR	G.E.					
3604	38	3		FUSE BLOCK	BUSS					
KAB-35	37	9		FUSE	BUSS	▷				
MS25226-4-2	36	8		BUSS BAR						
MS27212-2-8	35	2		TERM. BOARD						
1311-32	34	3			CAMBION					
1533-33	33	4								
1331-32	32	1		TERM. BOARD	CAMBION					
307594	31	3		TRANSFORMER	AIRESERCH	▷				
1431-32	30	1		TERM. BOARD	CAMBION					
68-00036	29	1		P.C. BOARD ASSY						
27	28	1								
15	27	1								
57	26	1								
45	25	1								
33	24	1								
24	23	1								
9	22	1								
51	21	1								
39	20	1								
30	19	1								
21	18	1								
68-00003	17	1		P.C. BOARD ASSY						
582381-9	16	1		CONNECTOR	AMP					
582383-9	15	5		CONNECTOR	AMP					
582384-9	14	6		CONNECTOR	AMP					
68-00064	13	1		TB #2						
68-00063	12	1		TB #1						
10-101960-183	11	1		PROTECTION CAP						
10-101960-163	10	1		PROTECTION CAP						
10-101960-149	9	2		PROTECTION CAP						
MS3122-14-19P	8	2		CONNECTOR						
MS3122-18-32P	7	1		CONNECTOR						
MS3122-16-26P	6	1		CONNECTOR						
1708-C	5	6		BUTTON, PLUG	G-C ELECTRONICS OR EQUAL					
418	4	2		BUTTON, PLUG	CINCH JONES OR EQUAL					
H 9110	3	2		HANDLE	BUD RADIO					
68-00068	2	1		BOX COVER						
68-00065	1	1		BOX ASSY						

PART NO.	NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY
APPLICATION			QTY REQD	
USAGE BLOCK				

30 AUG 68

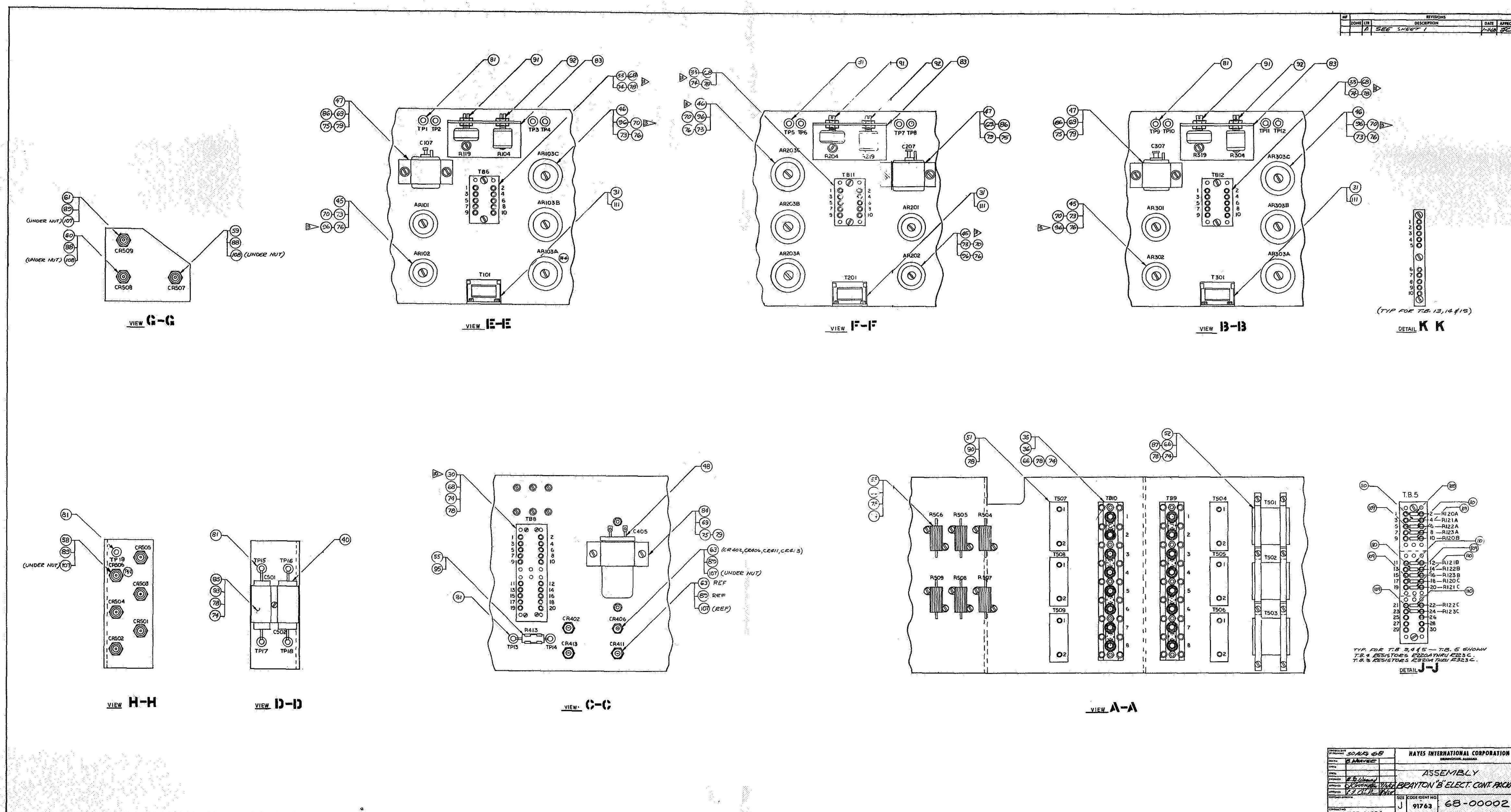
HAYES INTERNATIONAL CORPORATION

ASSEMBLY BRAYTON "B" ELECT. CONT. PKG.

SIZE J | CODE IDENT NO. 91763 | 68-00002

NASS-11784

SHEET 1 OF 2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VIEW F-F
VIEW B-B
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VIEW H-H
VIEW D-D
VIEW C-C
VIEW A-A
DETAIL J-J
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ASSEMBLY
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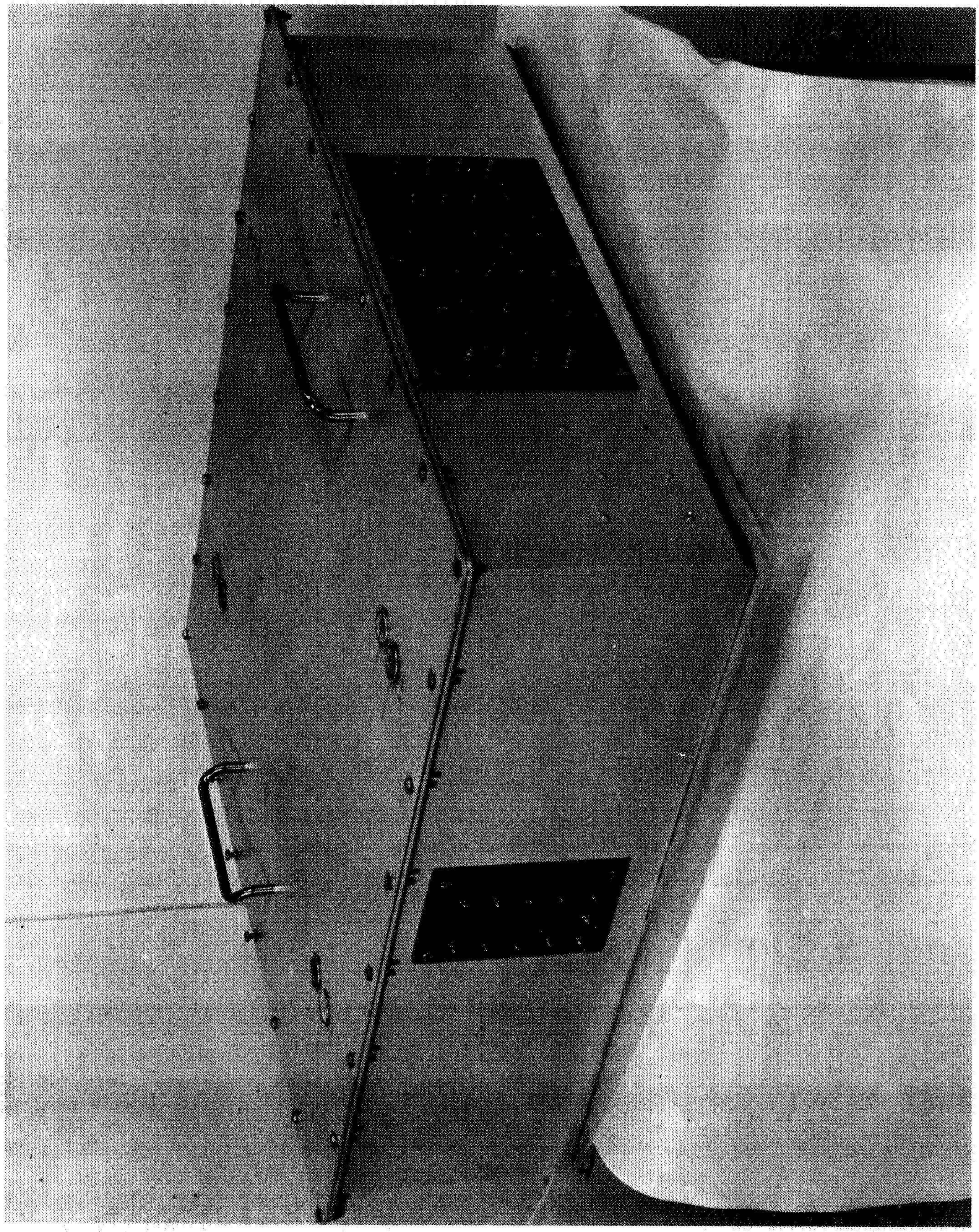

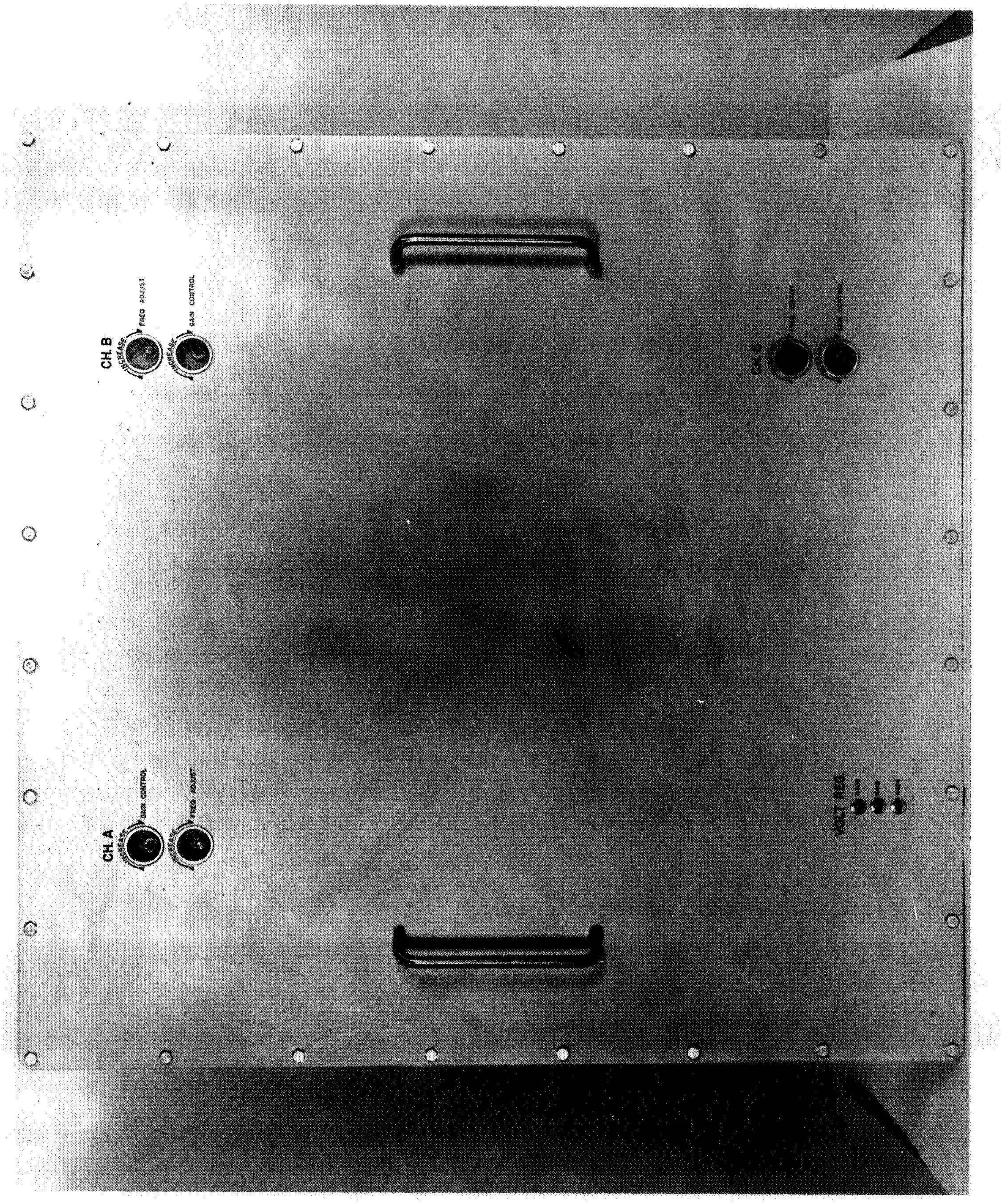
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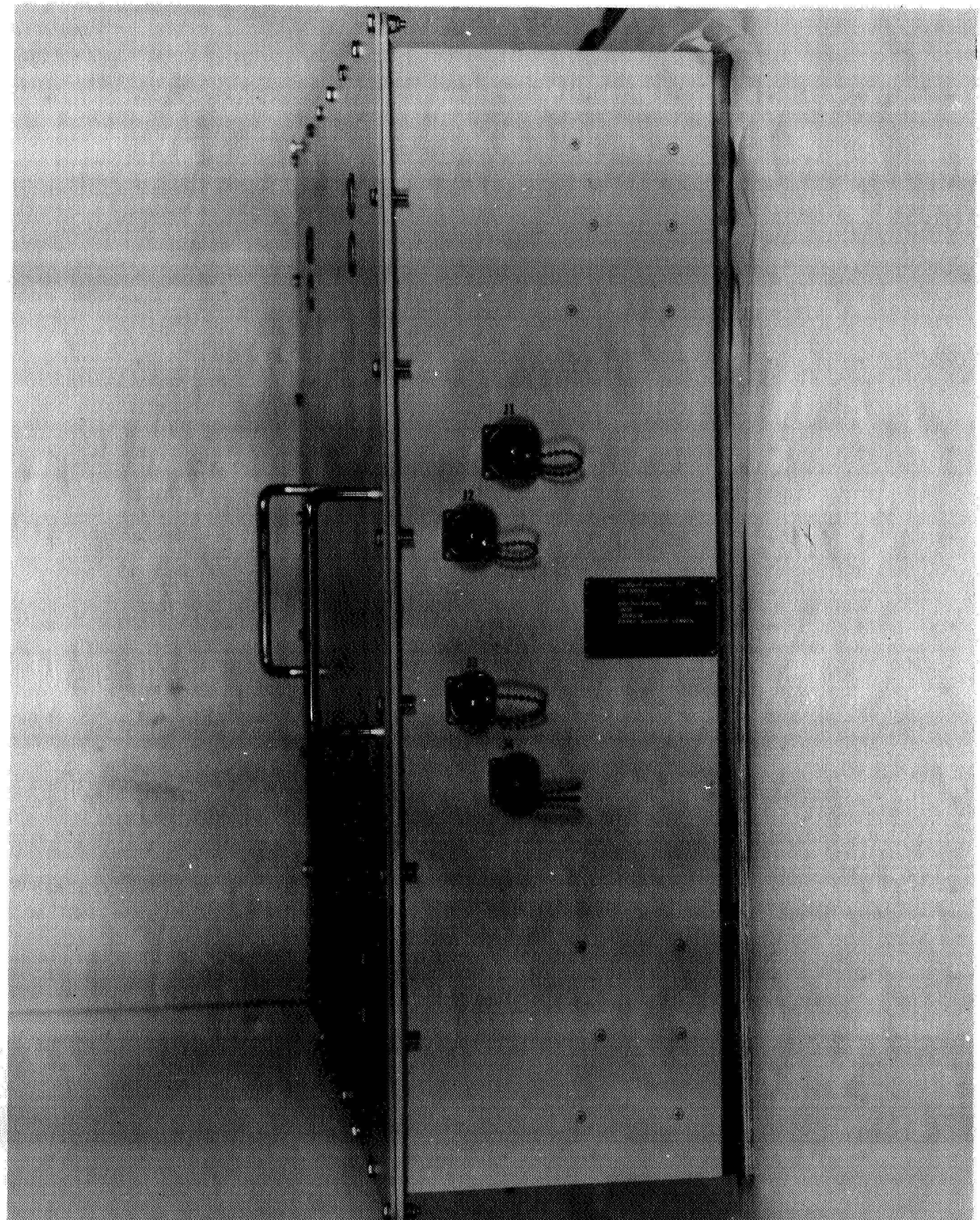

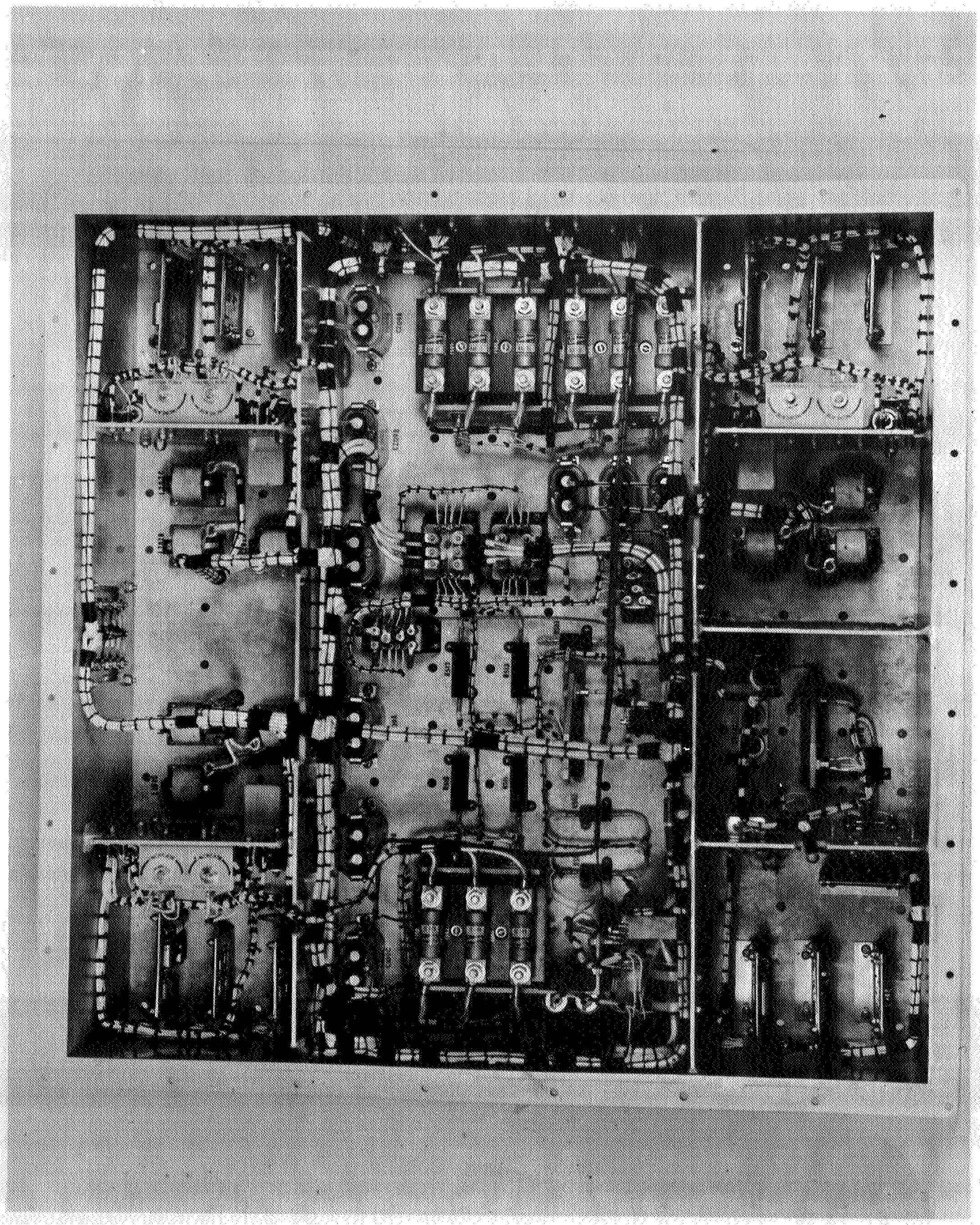

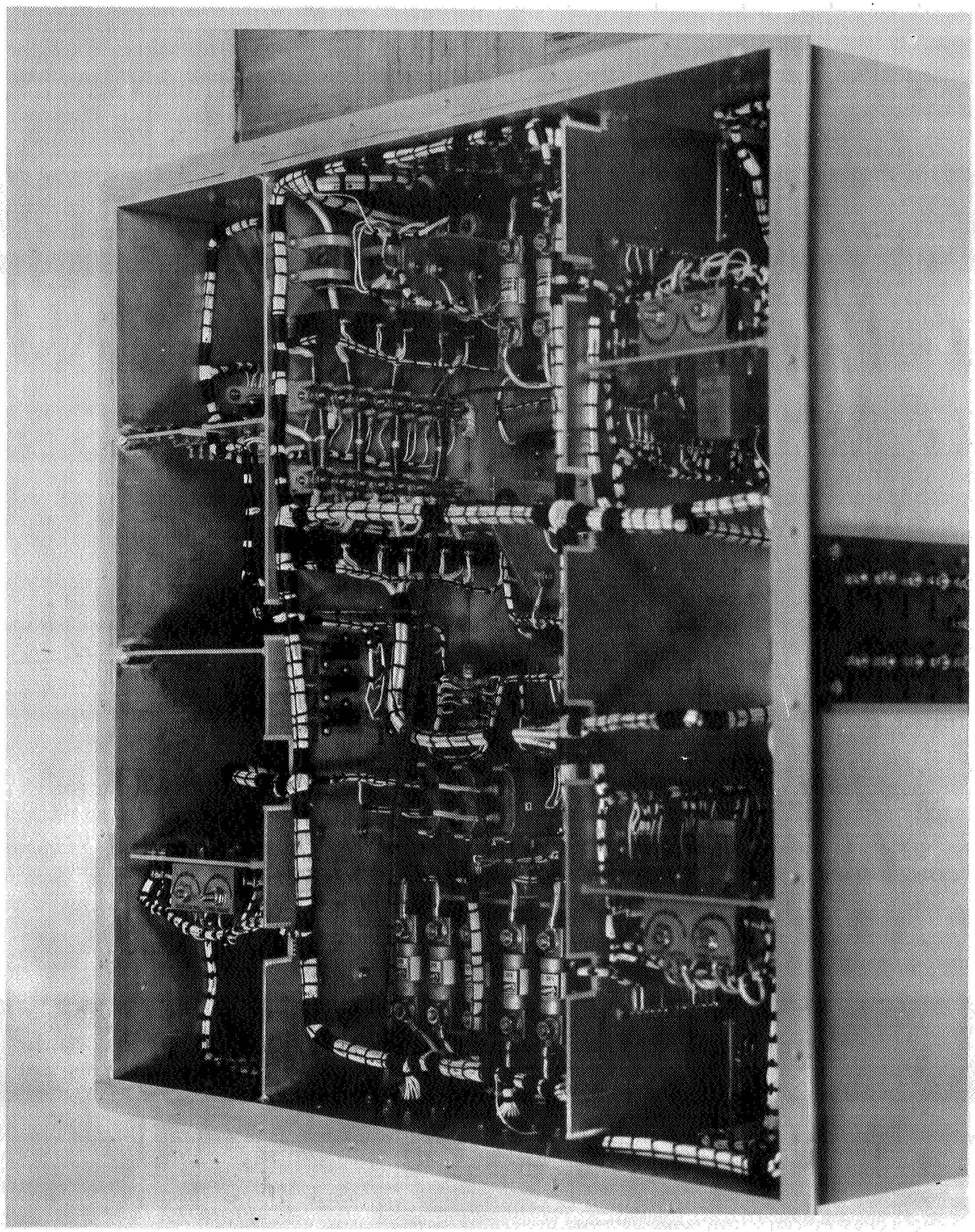

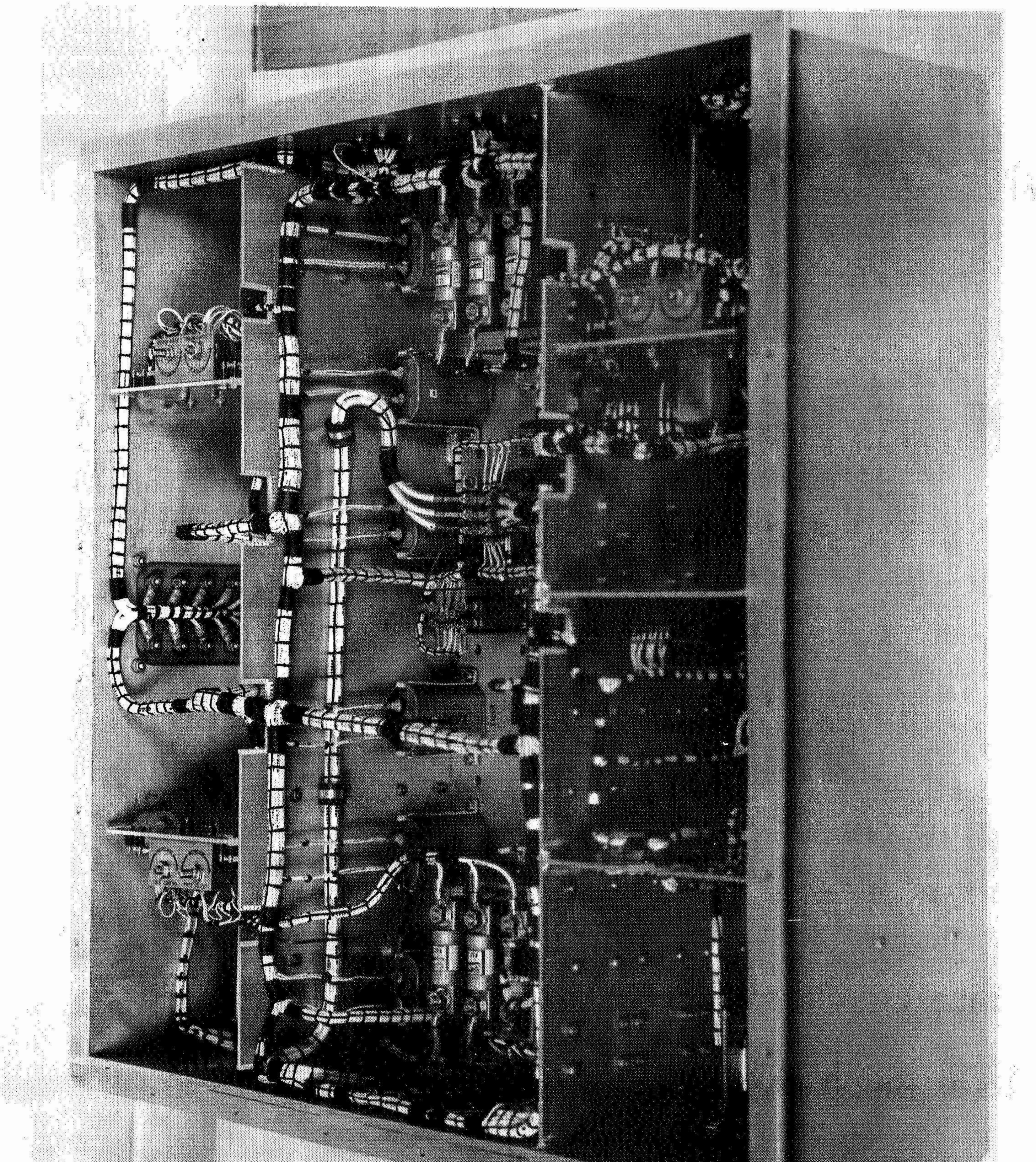

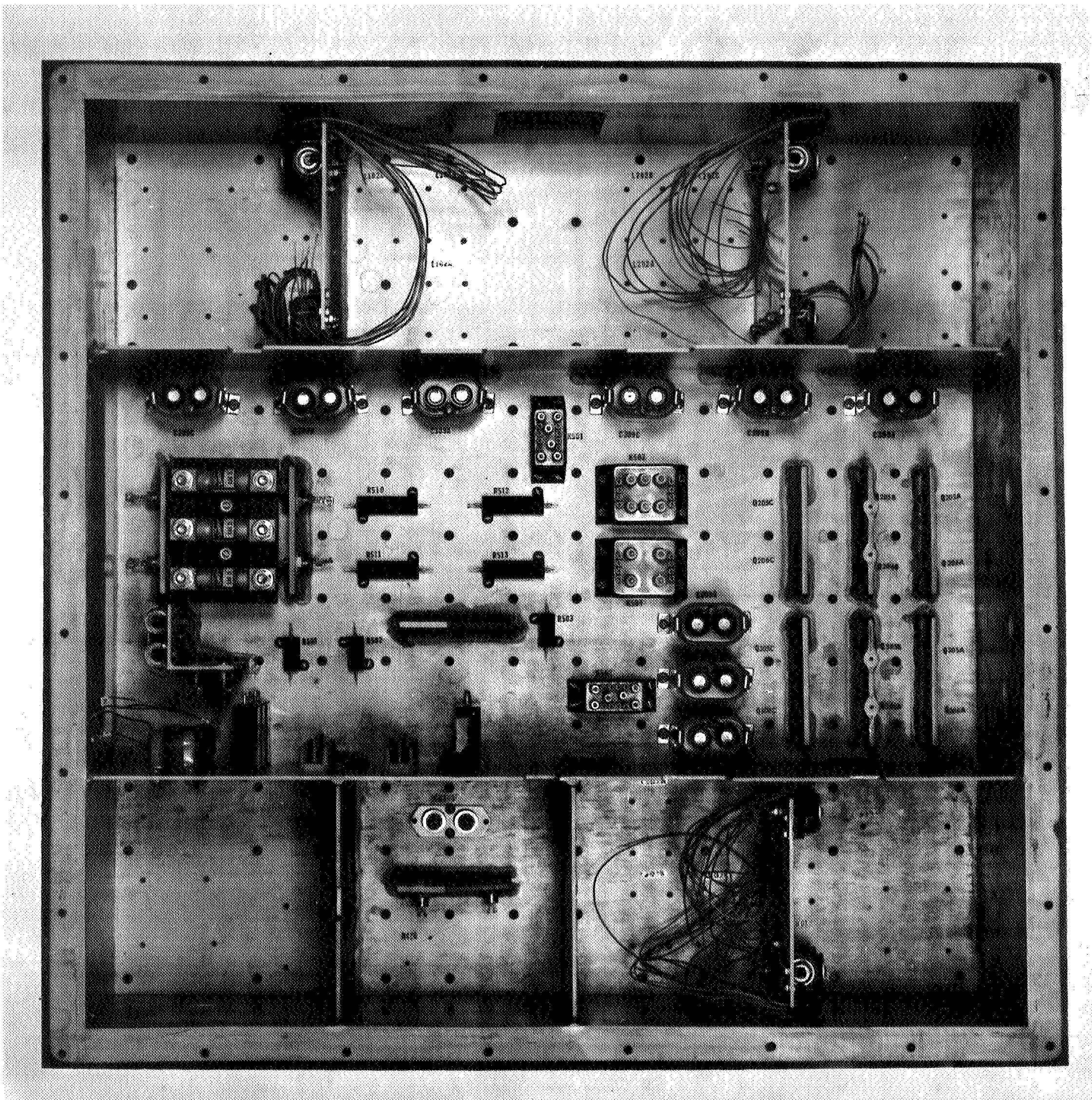

ELECTRICAL CONTROL PACKAGE
FOR
BRAYTON POWER CONVERSION SYSTEM

HAYES INTERNATIONAL CORPORATION
MISSILE AND SPACE SUPPORT DIVISION

ABSTRACT

The contract covered the packaging design, manufacturing and low power testing of the Electrical Control Package for the Brayton Power Conversion System. The Electrical Control Package regulates the alternator output voltage and frequency and serves as the distribution center for the alternator output power.

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